INFLUENCE OF VARYING LEVELS OF AMMONIUM CHLORIDE ON URINE pH AND SPECIFIC GRAVITY, OVERALL FEED CONVERSION AND WATER CONSUMPTION IN MATURE WETHER GOATS

A Thesis

by

MATTHEW JOSEPH KENNEDY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2008

Major Subject: Animal Science

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Approved by:

Chair of Committee,	W. Shawn Ramsey
Committee Members,	Thomas E. Spencer
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ABSTRACT

Influence of Varying Levels of Ammonium Chloride on Urine pH and Specific Gravity, Overall Feed Conversion and Water Consumption in Mature Wether Goats. (May 2008)

Matthew Joseph Kennedy, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Shawn Ramsey

The objective of this study was to evaluate the effect of orally administered ammonium chloride (NH_4CL) on pH and specific gravity of urine, overall gain, and water consumption in mature wethers on a grower/finisher ration. Obstructive urolithiasis, or urinary calculi, is a common problem in sheep and goat production systems utilizing a high grain diet, particularly one high in magnesium. Maintaining animals on a 70 to 90% concentrate ration is most conducive to the formation of urinary calculi. Boer cross wethers (n = 24) were stratified by body weight and randomly assigned within strata to one of three treatment groups. Wethers were placed on a common diet containing 2% NH_4Cl during the three week collection period. Treatment consisted of daily oral dosages of 0g NH_4CL (CON), 5.85 g NH_4CL (TRT 1), or 13.8g NH_4CL (TRT 2). Urine collected from TRT2 tested more acidic on the second and fourth collections before coming back linear constant with both the control (CON) and TRT1 . There was no effect of treatment ($P < 0.001$) on specific gravity of urine. Weight gain was greater ($P < 0.01$) in TRT1 (4.15 kg) and TRT2 (4.48 kg) as compared to CON wethers (2.95 kg). Water consumption was the most variable of all investigated objectives; all groups began with a linear increase for the first 4 d. Treatment 2 ($P < 0.001$) then showed significant increase at collections 2 and 4. Treatment 1 stayed more linear with the control with minimal increases ($P < 0.001$) occurring at periods of more acidic urine.

This study indicates that administration of NA_4Cl had minimal effect on urine pH, water consumption, and overall gain, but no effect on specific gravity.

To my loving parents and my two best friends who will never get the chance to see this

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Shawn Ramsey, and my committee members, Dr. Thomas Spencer, Dr. Chris Skaggs, and Dr. Chris Boleman, for their guidance and support throughout the course of this research.

Thanks also go to my friends, colleagues, and the faculty and staff for making my time at Texas A&M University a great experience. I especially want to thank Miss Samantha Cunningham for all of her support and assistance throughout this endeavor. I would also like to thank Mr. Jeff Thayne, Dr. Wesley Bisset and the sheep and goat center crew for their assistance during this study. Although there are too many to name, I am thankful for the support I have had from my friends as I have taken on this task. I appreciate the opportunities to interact with such great people and friends during my time at Texas A&M.

Finally, thanks to my parents for their patience and persistence, and for instilling me with a strong work ethic and the motivation to achieve my goals. Also thanks to God for giving me this opportunity.

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INTRODUCTION

Obstructive urolithiasis, or urinary calculi, is a common problem in sheep and goat production systems utilizing a high grain diet (Senthilkumar et al., 2001). Maintaining animals on a 70 to 90 percent concentrate ration is very conducive to the formation of urinary calculi (Kimberling and Arnold, 1983). Small ruminants and feedlot steers often present multiple calculi within the urinary tract, whereas affected ruminants maintained on pasture usually present with only one urolith (Van Metre et al., 1996). A study of feedlot lambs showed that four percent of all feedlot mortality was a result of urinary tract disease. Of these deaths, 97 percent were due to obstructive urolithiasis (Kimberling and Arnold, 1983). Urolithiasis is a problem almost exclusively of males with obstruction occurring most commonly in the urethra (Van Mettre et al., 1996). In goats, young castrated males maintained on a high grain diet are most likely to be affected with stones comprised mostly of phosphate salts (Kimberling and Arnold, 1983; Gutierrez et a1., 2000). This disease is characterized by formation of calculi within the urinary tract that can lead to retention of urine, abdominal pain, rupture or distention of the urethra or bladder, and possibly death from uremia or secondary septicemia if left untreated (Kimberling and Arnold, 1983). A variety of factors can lead to the formation of uroliths within the urinary tract: decreased water consumption leading to increased urine concentration, urine stasis, and increased urine pH leading to the perception of phosphate calculi, and diet composition that leads to increased mineral loss and also decreases protective colloids that inhibit precipitation in the urine (Gutierrez et al.,

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This thesis follows the style of Journal of Animal Science.

2000). When the urine pH increases, ion aggregation and crystal formation follow.

Supplementation of the diet with an additive capable of acidifying urine while increasing water consumption is recommended (Stratton-Phelps and House, 2004). Ammonium chloride (NH_4C1) has been recommended for use at a concentration of one to two percent of dry matter intake to adequately acidify urine and to treat or prevent uroliths. Crookshank et al. (1970) found when comparing several mineral salts for urinary calculi treatment, ammonium chloride was a more effective treatment and also increased the feed efficiency in lambs. Due to the fact that a high percentage of animals in the United States, as well as the world, are fed in a confinement type situation on high concentrate diets, it becomes financially advantageous to discover what process and additives may be used to reduce the risk of urinary calculi.

LITERATURE REVIEW

Types of Urolithiasis

Urolithiasis is a common sub-clinical condition among ruminants raised in management systems where high grain diets are utilized or when grazing certain types of forage (Radostits et al., 1994). Urine is highly concentrated with a large number of solutes, many of them in higher concentrations than their individual solubilities permit in solution (Radostits et al., 1994). Even so, numerous factors can predispose the perception of minerals from urine leading to calculi formation. These factors include a decrease in water consumption leading to urine stasis, increased urine concentration, increase in pH leading to the perception of phosphate calculi, and diet composition that leads to increased mineral loss and also decreases protective colloids that inhibit precipitation of the urine (Gutierrez et al., 2000).

Phosphatic calculi are formed in response to a high-concentrate low-roughage with a low calcium-to-phosphorus ratio, high-magnesium diets, and alkaline urine (Hooper, 1998). Lambs fed a diet high in phosphorus and magnesium had a high incidence of calculi on postmortem examination (Pugh, 2002).

Silicate calculi also are occasionally diagnosed (Anderson, 1998). They occur more often in sheep fed plants grown in sandy soil or water containing high levels of silica, conditions that are common in western North America (Bailey, 1981). Diets high in silica along with high calcium-to-phosphorus ratios, that are supplemented with sodium bicarbonate may predispose the formation of silica calculi (Stewart et al., 1990).

Oxalate calculi are caused by the ingestion of excessive quantities of oxalate-containing plants including the Greasewood, found in the western U.S., and the Halogelen, found mostly in Nevada (Pugh, 2002). Oxalates bind calcium in the rumen, but bacteria in a healthy rumen may adapt enzymatic mechanisms that more effectively degrade oxalates. All uroliths are composed of salts and minerals in a crystal lattice surrounding an organic matrix (nidus) of pertinacious material. Nidus formation occurs when urine mucoproteins coalesce and precipitate with crystals within supersaturated urine. Urinary mucoprotein production is increased by estrogenic compounds, inadequate levels of vitamin A, and high-concentrate diets (Divers, 1996).

Acidic urine (pH less than 7.0) predisposes to the formation of silicate calculi. Alkaline urine (pH greater than 7.0) favors the formation of phosphate, carbonate, and struvite calculi. Oxalate calculi may form in either acidic or alkaline urine. Forage-based diets commonly contain excessive amounts of potassium, which can result in an alkaline urinary pH.

Renal function and Calculi Formation

The kidney is a complex organ that has important biological roles, with the primary role being maintaining homeostasis of bodily fluids. Kidneys are made up of an external cortex and an inner medulla; together, they are responsible for sending out surpluses of water, salts, minerals and other waste products of metabolism. These waste products are filtered from blood, which is transported into the kidney through the renal artery and returned to the blood stream through the renal vein after filtering. Waste products are excreted as urine and are collected in the renal pelvis, which then drains to the bladder via the uetera. Urine travels from the bladder, by way of the urethra, through the ischial arch of the pelvis, the sigmoid flexure, the urethral process, and then finally excreted from the body (Raflesia, 2008).

The most common sites of obstruction are the urethral process and distal sigmoid flexure, although the trigone of the bladder, the urethra, and the renal pelvis also may become obstructed (Holland et al., 2000). Age at castration, sex, water intake, and mineral profile of water all play a role in susceptibility to urolithiasis. Young castrated males tend to be the most susceptible in the caprine species. Early castrations decrease the urethral diameter increasing the incidence of obstruction. This also holds true across species as large ruminants are compared to small. Urinary tract size is the major factor influencing the higher rate of urolithiasis in small ruminants as their tract size does not allow passage of pass mineral build-ups, or stones, while cattle and other large ruminants having larger urethras are able to pass these deposits without blockage.

Among the factors known to cause urolithiasis, mineral imbalance, particularly calcium, phosphorus and magnesium have the greatest effect on ruminant animals (Bellenger et al., 1981). Ruminant animals on a high forage diet will have more salivary production and phosphorus will be excreted through feces. High-grain diets cause an overwhelmed salivary excretion mechanism limiting saliva production, resulting in the excretion of large amounts of phosphorus in the urine (Pugh, 2002). This occurs as phosporus is filtered by the kidney and sent as waste, in the form of urine, to the bladder. The phosphorus then settles out in the bladder forming large deposites leading to stone formation (Raflesia, 2008).

As a general rule, the calcium-to-phosphorus ratio should be maintained between 1:1 and 2:1. Cereal grains have an abnormal calcium-to-phosphorus ratio of 1:4 to 1:6. High-calcium diets are effective at reducing the absorption of phosphorus from the gastrointestinal tract; legumes (e.g., alfalfa, clover) have much more calcium than phosphorus. Increased levels of magnesium in diets with normal calcium and phosphorus concentrations can cause an increased incidence of urolithiasis in feedlot lambs (Stewart et al., 1991).

Activity and Effects of NH_4Cl Supplementation

Ammonium chloride has been used many ways and has various effects of induced acidosis on the metabolism of various macro elements (Horst and Jorgensen, 1974). It has been shown to increase calcium excretion in urine in both humans (Lemann et al., 1965) and sheep (Braithwaite, 1972), thus causing less incidence of urolithiasis in both species due to decreased phosphorus in the urine (Bushman et al., 1967). Ammonium chloride has been shown to be the most effective urine acidifying compound (Crookshank, 1970) and when added to ruminant diets decreases the incidence of silica uroliths (Stewart et al., 1991). Whenever acidifying products are fed, urine pH should be monitored. Urine pH should be maintained at or slightly less than 6.8. Ammonium chloride (200 to 300 mg/(kg * day) or 2% of the total diet) appears effective in maintaining proper pH, but it is extremely unpalatable (Hooper, 1998). In a study by Horst and Jorgensen (1974), NH_4Cl supplementation caused a decrease in dry matter intake, a decrease in urine pH, an increase in total grams of urine excreted per day, and an increase in total urinary excreation of nitrogen, calcium, magnesium, chloride, strontium, and zinc.

The biochemical and anticalulogenic effect of ammonium chloride, while supplemented with high magnesium rations, was investigated by Senthilkumar et al. (2001). Twelve male Malabari goats of 9 to 12 months age were selected and divided into two groups of six animals. Two rations were prepared. Ration A was a concentrate fortified with calcium oxide, phosphorus pentoxide and magnesium oxide to limit the estimated levels of 0.84, 0.51 and 0.31 percent of calcium, phosphorus and magnesium respectively. Ration B was constituted by using calculogenic ration supplemented with ammonium chloride to the extent of 1 percent. Animals in groups 1 and 2 were fed with rations A and B respectively. In this study (Senthilkumar et al., 2001), goats fed rations containing supplemental ammonium chloride had a slight reduction (8.4 to 8.0) in urine pH along with an appreciable increase in urine volume (1861 ml/day) as compared to animals maintained under group 1 (1413 ml/day). Reduction of urine pH may be attributed to the excess chloride ions supplied by the supplemental ammonium chloride due to saturation of urine caused by increased fluid consumption (Bushman et al., 1967). These results also suggest that supplemental ammonium chloride significantly suppressed the effect of high dietary magnesium on serum calcium, phosphorus, and magnesium, and maintained their levels within the normal range (Bushman et al., 1967). Ammonium chloride has also been compared with other ammonium salts of strong anions such as ammonium sulfate and diammonium phosphate to examine its effectiveness. Ammonium chloride was the most effective ammonium salt, producing the least amount of obstructive urolithiasis cases (Crookshank, 1970).

Many studies have concluded that the addition of ammonium chloride at the rate of 0.5 to 1.5% of total diet will acidify the urine to protect against calculi (American Sheep Industry 2007, Jurgens, M.H. 1974), but calculi remains a problem that is faced by commercial feeders and show wether owners, even if precautions such as the addition of ammonium chloride at suggested levels in the animals daily ration have been taken to avoid urolithiasis.

Specific Gravity

Specific gravity measures the kidney's ability to concentrate or dilute urine in relation to plasma. Urine is a solution of minerals, salts, and compounds dissolved in water, and it has a specific gravity greater than 1.000. As urine becomes more concentrated, specific gravity increases. Kidneys of older animals are able to concentrate or dilute urine more efficiently in comparison to immature kidneys (Weeth et al., 1969). In a study conducted by Weeth et al. (1969) measuring the specific gravity of urine from Hereford heifers, the mean and standard deviation for specific gravity was 1.024 $\pm$ 0.00783, with a range of 1.0030 to 1.0413. From the fiducial limits, it can be predicted that ($P <$ 0.05) the specific gravity of a sample ranges between 1.0189 and 1.0301. These levels should hold constant through water deprivation and stress, as the cattle were on water deprivation for four days and offered ad libitum water the following four days through this eight day trial.

Genetic Factors

Genetic factors may play a role in the excretion of salts by the kidney and the production of crystal-inhibiting compounds appears to differ among animals of the same species (Pughs, 2002). Calculi in the Dalmation formed form urate (salts and uric acid) and can cause urethral obstruction. Pedigrees from a survey of six-year-old Dalmations showed the heritability of the clinical manifestation of urate calculi within the breed to 0.87. The prevalence of the disease was 34% among males in the given study (Bannasch et al., 2004)

Heritability is also seen in human studies. In a cross-sectional study in Tabriz, a total of 210 patients with upper urinary tract calculi were evaluated (Ahmadi Asr Badr et al., 2007). Of the 210 patients evaluated, 28.6% had a positive family history for urinary calculi. Siblings were the majority of affected family members (71.1%). The rate of positive family history was numerically higher in women than in men, 0.30 and 0.281, respectively. Calculi were more often detected in the left renal unit, but calculi were more prevalent on the right side in patients with a positive family history of urinary calculi. There was no relationship between family history and the number or size of calculi (Ahmadi Asr Badr et al., 2007).

Prevention and Treatment

Access to fresh clean water encourages water consumption and decreases the concentration of minerals in the urine, thus decreasing the incidence of urolith formation. In the winter, warming the water may increase consumption (Anderson, 1998). Sodium chloride added at the rate of 3 to 5% of the dietary dry matter intake has shown to increase water consumption. The chloride ions may reduce super saturation of calculus-forming salts (Gohar and Shokry, 1981; Kimberling and Arnold, 1983). Chloride has the ability to prevent phosphates from binding to the mucoprotein matrix that forms as part of the struvite molecule. The addition of salt can help prevent phosphate, magnesium, and silicate-based calculi. An anionic diet increases the urinary excretion of hydrogen ions, decreases urinary pH, increases urinary excretion of calcium, and decreases the precipitation of struvite (Pugh, 2002). Conversely, diets and feedstuffs rich in cations (e.g., alfalfa, molasses) should be avoided as anionic diets are more favorable to prevention of calculi production. Grass hays should be considered the primary forage source for males because grass has a more favorable cation-to-anion balance than legumes for struvite prevention. To avoid precipitation of magnesium and calcium phosphate, urine pH should be maintained or below 6.8 (Hoar et al., 1970).

Balancing levels of calcium, phosphorus, and magnesium in the diet is important to prevent urolithiasis. If the magnesium content of the diet is greater than 0.6%, struvite uroliths may occur even if a normal calcium-to-phosphorus ratio exists (Anderson, 1998). Adding calcium to the diet may help reduce intestinal uptake of phosphorus and magnesium. Therefore, analyzing the diet and adding calcium carbonate or calcium chloride to the diet to attain a 2:1 calcium-to-phosphorus ratio are excellent techniques to reduce the incidence of urolithiasis (Van Metre et al., 1996).

RATIONALE

The ability of NH_4CL (ammonium chloride) to acidify urine makes it an attractive option to aid in the treatment and prevention urinary calculi. Goat producers are interested in the health of both wethers and reproductive males. The ability to use NH_4CL as a urine acidifier to aid in prevention of calculi could prove beneficial. The capacity of NH_4Cl to act as a urine acidifier in wethers needs further investigation.

HYPOTHESIS

The addition of high levels of NH_4CL to a wether diet should increase the acidity of urine due to its mildly acidic nature, thus aiding in the decrease of calculi formation and the maintenance of specific gravity. It also should increase water consumption and effect gain due to increased nitrogen production in the small intestine.

OBJECTIVE

The objective of this study was to evaluate the effect of oral dosing of ammonium chloride (NH_4CL) on pH and specific gravity of urine, overall gain, and water consumption in mature wethers on a grower/finisher ration.

MATERIALS AND METHODS

Animal Care

Twenty-four 10-12 month old Boer-cross show wethers were obtained through a commercial source, weighed and stratified by body weight, and randomly assigned within strata to one of three treatment groups. All goats were placed on a commercial show goat feed (Producers Cooperative Association; Bryan, TX) containing 2% ammonium chloride at the rate of 1.36 kg per head per day (Table 1).

Housing and Management

During the trial, goats were housed at the Texas A&M Sheep and Goat Center, within the O.D. Butler Animal Science Complex that is 8.5 km west of College Station, Texas. All animals were housed within one of three treatment groups in soil surfaced pens with bunk type feeders, such that each goat had a minimum of 38.1 cm of linear trough space and 6.9 square meters of pen space. Animals were provided with *ad libitum* access to water, which was contained in three 5-gallon hard plastic buckets and changed daily after residual intake was measured.

Diets

Goats were fed 1.36 kg/animal of a commercial goat feed containing 2% ammonium chloride for 14 days prior to data collection and during the 21 days collection period. Goats were provided with *ad libitum* access to water, and intake was measured and recorded

Table 1. Diet composition for experiment.

Ingredients	Guaranteed Analysis
Crude Protein	15%
Crude Fat	3.4
Crude Fiber	14.25
Calcium	0.75
Phosphorus	0.4
Salt	0.95
Copper	27 ppm
Selenium	0.3 ppm
Vitamin A	12,000 iu/lb

Treatment Application

Treatment consisted of 0 g NH_4CL (CON), 5.85 g NH_4CL daily (TRT1), or 13.8 g NH_4CL daily (TRT2). Administered orally in a Kayro® Syrup paste with the syrup (10cc) being used as a carrier in order to mask the flavor. The paste was administered using a 20 cc LUERLOCK® syringe from which the end had been removed. Paste was administered daily at 0800 hours.

Data Collection

Urine samples were collected on days 1, 4, 7, 9, 12, 15, 18, and 21 at 0700 hours prior to feeding and treatment. Samples were collected in sterile plastic urine cups, and transported to the laboratory for evaluation immediately after the last collection.

Urine pH was measured using a Cardy Twin pH Meter (Spectrum Technologies, Plainfield, IL.). Calibration was performed at the beginning of sample analysis as per the manufacturer's instructions and recalibrated every ten samples thereafter. Urinanalysis was completed within 4 hours of collection. A standard refractometer was used to evaluate the specific gravity of the urine.

All goats were weighed at the start of the trial (day 0) and again at the end (day 21).

Data Analysis

This experiment was analyzed using the General Linear Models, the procedures of statistical analysis system (Version 9.1.3 SAS Institute, Cary, NC). Analysis included effects of treatment day and their interaction (treatment * time).here appropriate, time data within treatment was analyzed by regression. Treatment effects were determined by orthogonal contrasts (TRT2 vs. CON and TRT1 vs.CON). Data is reported as least squares means (LSM) with standard error (SE)

RESULTS AND DISCUSSION

Urine pH

Hooper (1998) found that feeding animals NH_4Cl at a rate of 2% of the total diet is effective in maintaining pH at or slightly below 6.8. In the current study, larger amounts of NH_4Cl were administered, combined with the 2% of NH_4CL in order to decrease urine pH. Urine pH was affected by treatment ($P < 0.01$) and day ($P < 0.01$) but not their interaction ($P = 0.18$). Overall, urine pH was not different ($P > 0.40$) in CON (7.64 $\pm$ 0.08) as compared to TRT1 (7.65 $\pm$ 0.09) but was lower ($P < 0.01$) in TRT2 wethers (7.2 $\pm$ 0.09) (Table 2).

Regardless of treatment, urine pH was high on day 1 (7.9 $\pm$ 0.1) and lowest on day 15 (7.1 $\pm$ 0.1)

Specific Gravity

Urine specific gravity was affected by treatment (P <0.001) day, ($P < 0.0001$) and their interaction (treatment * day, $P = 0.0034$). In CON wethers, urine specific gravity was affected by day (quartic effect of day, $P = 0.02$). Secific graviy was high on day 1 decreased on day 4, increased again to day 12, and then declined thereafter. In TRT1 wethers, Urine specific gravity was affected by day (cubic effect of day, $P = 0.02$). In TRT2 wethers , urine specific gravity was day (linear effect of day, $P < 0.0001$). Specific gravity was highest from days 1 to 12, decreased to day 15, and then increased to day 21. Specific gravity declined from day 1 to day 21 (Figure 1).

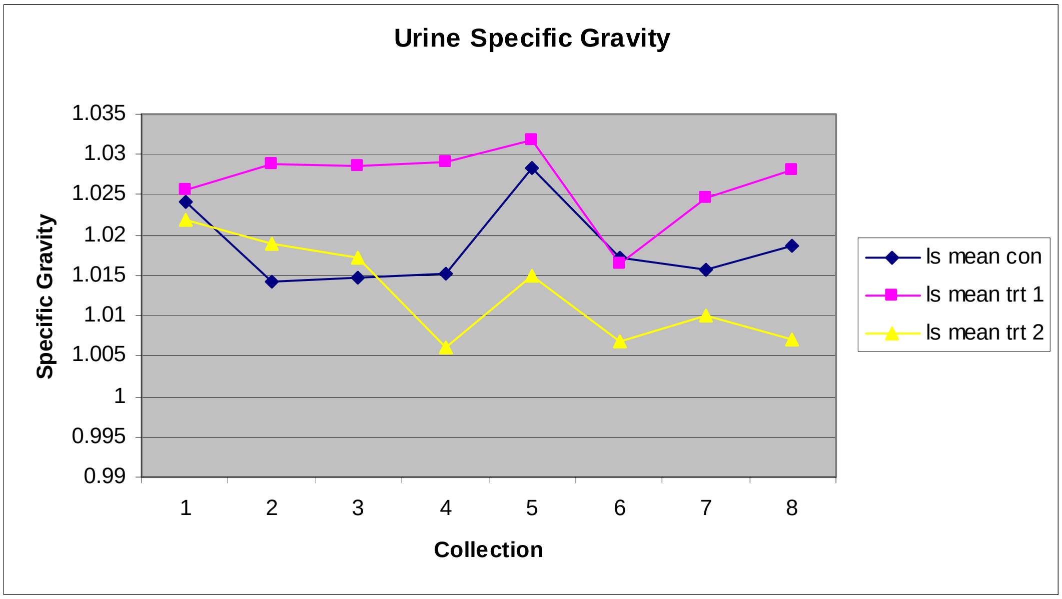

Figure 1. Urine Specific Gravity

Table 2. Average pH of urine within treatment groups by collection.

	Treatment		
Day	**CON**	**TRT1**	**TRT2**
–			
Day 1			
pH	7.78	7.97	8.06
Day 4			
pH	7.55	7.45	6.71
Day 7			
pH	7.73	8.12	7.37
Day 9			
pH	7.67	7.55	6.41
Day 12			
pH	7.83	7.53	7.63
Day 15			
pH	7.16	7.00	7.13
Day 18			
pH	7.52	7.56	6.97
Day 21			
pH	7.89	8.00	7.60

Collections were performed on days 1, 4, 7, 9, 12, 15, 18, and 21

[a]SE = 0.01

Weight Gain

An advantage in weight gain was exhibited by the treatment groups over the 21 day period with treatment 2 showing the most gain (4.48 kg) for this period. Treatment 1 also showed significant gains (4.15 kg) while the control group showed minimal gains (2.95 kg) (Table 3). These results coincide with results by Crookshank (1970), which showed an increased feed conversion on wether lambs when ammonium chloride was added to the ration. An increase in feed conversion in swine has also been reported when ammonium chloride was added to the diet (Clawson and Alsmeyer, 1971).

Water Intake

The mean for water consumption across treatments was CON 24.78 $\pm$ 2.77 L, TRT 1 27.01 $\pm$ 3.17 L, and TRT 2 32.21 $\pm$ 4.81 L. With the daily average intake/goat being CON 3.142 L, TRT 3.255 L, TRT 2 4.012 L. Water consumption was the most variable of all investigated objectives; all groups began with a linear increase for the first 4 d. Treatment 2 then showed significant increase in relation to both treatment 1 and the control group, with the first two notable increases coming in relation to a more acidic urine. Water consumption increased when sodium chloride, another acidifier, was added to the diet at a rate of 3-5% the dietary dry matter intake (Gohar and Shoky, 1981; Kimberling and Arnold, 1983) Even so, the variability of treatment 2 still ranged from 5.75 gallons to 10 gallons daily (Table 4).

Treatment 1 stayed more linear constant with the control with minimal increases occurring at periods of more acidic urine. While all treatments showed a drastic decline in consumption at days 14 and 15 (Figure 2).

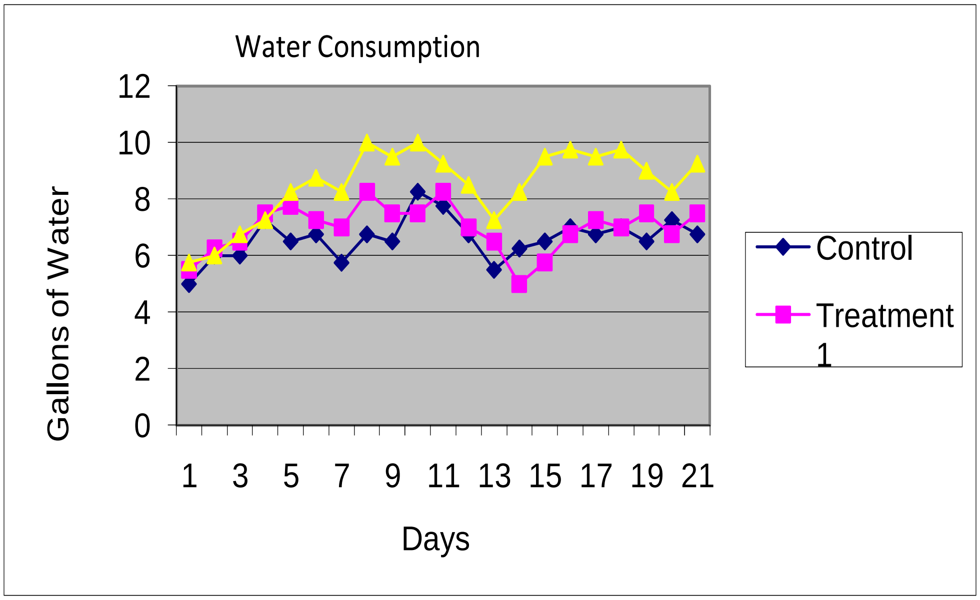

Figure 2. Water Consumption

Table 3. Weight change from day 0 to day 21.

	Treatment		
Item	**Control**	**Treatment 1**	**Treatment 2**
Day 0	44.32 kg	43.9 kg	44.87 kg
Day 21	47.27 kg	48.05 kg	49.35 kg
Change in weight	2.95 kg	4.15 kg	4.48 kg

Table 4. Daily water intake across treatments.

	Treatment		
Item	**Control**	**Treatment 1**	**Treatment 2**
Day 1	5	5.5	5.8
2	6	6.3	6
3	6	6.5	6.8
4	7.3	7.5	7.3
5	6.5	7.8	8.3
6	6.8	7.8	8.8
7	5.8	7	8.3
8	6.8	8.3	10
9	6.5	7.5	9.5
10	8.3	7.5	10
11	7.8	8.3	9.3
12	6.8	7	8.5
13	5.5	6.5	7.3
14	6.3	5	8.3
15	6.5	5.8	9.5
16	7	6.8	9.8
17	6.8	7.3	9.5
18	7	7	9.8
19	6.5	7.5	9
20	7.3	6.8	8.3
21	6.8	7.5	9.3
Average	6.7	6.9	8.5

Water was measured daily.

CONCLUSION

This study indicates that high dosages of NH_4Cl, given in addition to normal levels found in commercial feed, had minimal effect on urine acidity for extended periods. Although spikes in urine acidity were exhibited within TRT2 wethers at days 4 and 9. Oral NH_4Cl had no effect on the specific gravity of urine regardless of dose. Treatment 2, receiving 13.8g NH_4Cl daily, showed the greatest increase in water consumption and overall weight gain, but still showed variation. Treatment 1, showed minimal gain for both water intake and overall gain. Diets of the goats in the study were unknown prior to the 14 day adaptation period preceding the study. All goats were show wethers, therefore most animals were more than likely exposed to urine acidifier at some point prior to the trial. It is possible that if goats were obtained from a more commercial source, where animals were not under extensive care, such as those seen in this trial, the effects of these increased levels of NH_4Cl might have been greater. It is another possibility that these levels of NH_4Cl have limited or no effect on urine pH and specific gravity, water intake, and overall gain. It may be necessary to challenge these animals and limit water consumption across treatments to induce a greater response from the application of this acidifier.

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