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Water and small ruminant production

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ABSTRACT - Water is a nutrient of extreme importance for animals and must be considered vital in any rearing phase. The increasing scarcity of this precious natural resource has concerned different segments of society in order to find solutions for rational and sustainable use of this nutrient. Small ruminants, especially sheep and goats, have social and economic importance due to their great ability in adapting to adverse environmental conditions and using water efficiently. Thus, they might be a good alternative to mitigate the climate change effects and to generate foreign exchange and improving life condition in many places of the world. The concept of water productivity for livestock production is relatively new and there are few studies in the world, especially in Brazil. More researches and new technologies for water use in livestock production are indispensable.

Key Words: climate changes, goat, salinity, sheep, water balance

A água e a produção de pequenos ruminantes

RESUMO - A água é um nutriente extremamente importante na vida dos animais e deve ser considerada como vital em qualquer fase da criação. A escassez crescente deste precioso recurso natural tem provocado reações de diferentes segmentos da sociedade na busca de soluções de uso racional e sustentável deste nutriente. Os pequenos ruminantes, especialmente os ovinos e caprinos, são partes importantes da vida econômica e social de muitas nações pela sua ampla capacidade de adaptação às condições adversas do ambiente e boa eficiência no uso da água, podendo ser uma das boas alternativas de mitigação dos efeitos das mudanças climáticas, gerando divisas e melhoria das condições de vida em muitas regiões do mundo. O conceito de produtividade de água para a produção animal é relativamente novo e ainda são recentes e escassos os estudos existentes no mundo e em particular no Brasil. A realização de mais pesquisas e a geração de novas tecnologias de uso da água na produção animal, hoje mais do que nunca tornam-se imprescindíveis.

Palavras-chave: balanço hídrico, caprino, mudanças climáticas, ovino, salinidade

Introduction

Water covers almost 98% of the molecules in the animal organism (NRC, 2001). It is distributed throughout the body including extra and intracellular fluids, which contains respectively, from 31 to 38% and from 62 to 69% of the overall body water. It is also considered the most abundant and vital chemical substrate of all living beings (NRC, 2007).

Water is already scarce for more than a billion people on the planet. If urgent measures are not adopted, one-third of the population may be without suitable water for consumption by 2025 (UNESCO, 2006). This possibility of water shortage also affects livestock, and therefore all procedures involving water use in animal production must be reviewed.

Small ruminants, especially sheep and goats, have social and economic importance in the entire world. Information about feeding habits and nutrient requirements of these animals is essential for managing their welfare and for contributing to the livelihoods of people that depend on them. Adequate nutrition and management of these small ruminants are important for their maintenance in different ecosystems from the Arctic Circle to the Sahara desert (NRC, 2007).

The world herd of goat and sheep is greater than 1.7 billion heads. China, Australia and India are the countries

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with larger herds in the world, with approximately 30% of the world herd. Most of these animals are found in arid and semiarid areas of the entire world. Just as in Brazil, where most of goat and sheep herd is found at the Northeast region, especially in the semiarid area.

The sheep and goats herd from the Brazilian semiarid is around 18 million heads, if an intake of 3 L/animal/day has been considered, 54 million of L of water/day would be necessary to supply these animals. That amount of water would be enough to supply 500 thousand people for one day, considering a *per capita* intake of 100 L/day. This value could be even higher if the amount of water of feedstuffs and the water used to produce these feed are considered, therefore the water volume required for livestock production is high and must be used with responsibility in order to increase its capture and use with positive effects for the productive systems.

Despite the great importance, the subject-matter “water” still needs more attention from scientific-technical researches, mainly when related to animal production. Plumb (1927) had already reported this fact and showed that the investigation of this subject in the production system of sheep is also too small. The number of researches and publications with sheep and goats is increasing in Brazil (Costa et al., 2009; Osório et al., 2009; Azevêdo et al., 2010; Oliveira et al., 2010; Gastaldello Jr. et al., 2010), but there are few that consider water as response variable (Neiva et al., 2004; Ribeiro et al., 2006; Medina et al., 2009; Araújo et al., 2009) or as the main subject of the study.

This paper aimed to show a review of national and international literature about water and small ruminants, presenting short discussions about related issues, such as water balance, water productivity, virtual water and other variables rarely evaluated in animal production.

Requirement and water sources

According to NRC (2007), the success of the nutritional management depends on supplying enough water for an animal so its water requirement is met by voluntary intake. However, determination of water requirement is a complex process that involves the solution of a water balance equation, where water intake (WI) must meet total water loss (WL) and retained water (RW).

Water can be fed to the animals from three sources: drinking water, feed water and metabolic water from nutrient catabolism (Esminger et al., 1990). Water use or ingestion by the animal is related to different variables: body weight; dry matter intake; energy intake; effects of year seasons (temperature, radiation and humidity); restriction effect (drinking trough availability and spacing), water quality, species, breed and different physiological stages: growing, pregnancy and lactation (NRC, 2007).

Water from feedstuffs is an important source for the animal. This additional water supply is more important to the animals reared in regions with little access to drinking water, as sheep and goats in the Brazilian semiarid region. Succulent feed with high water concentrations and low dry matter contents, such as forage cactus, mandacaru, fresh grasses and legumes, forage watermelon and silage, constitute important sources of water for goats and sheep reared in this region.

Araujo (2009) observed that diets containing high concentration of forage palm supplied great water amount to the animals, higher than 4.0 L water/animal/day only from this source. The water balance of these animals was similar to those that ingested large amounts of water directly from the drinking troughs.

Metabolic water is generated from nutrient catabolism and is a strategy source of water availability for the animal. As example, when 100 g carbohydrate is oxidated, 60 g of water is produced. In protein oxidation 42 g of water is generated from each 100 g of protein. In the oxidation of 100 g of fat approximately 110 g of water is produced. However, there are water losses in the oxidation process, and in the case of fat oxidation there is an increase of breathing with higher water losses by the lungs, then fat hydrolysis produces less metabolic water when compared to the carbohydrate hydrolysis (Ensminger et al., 1990).

When different animal species and body weights are evaluated, a first approach to estimate water use can be obtained from the relations between water and total body weight requirements. When water is promptly available, total intake (WTI = intake of available water, WAI + feedstuff water, FW) correlates with dry matter intake (DMI) for diets with adequate nitrogen levels, which, according Forbes (1968) and NRC (1985), cited by NRC (2007), can be expressed by the equation: WTI = 3.86 x DMI – 0.99 (Figure 1). In this case, a dry matter intake of 1 kg would result in a water intake of 2.87 L.

The physiological stage also affects water ingestion. Water requirement increases by 126% from the first to the fifth month of gestation in sheep. Thus, water intake:dry matter intake ratio (WI/DMI) is from 4.3 to 5.2 L/kg, in pregnant sheep with only 1 fetus and from 7 to 8 L/kg in sheep with two fetus. This represents almost two times the maintenance requirement (2 to 3 L/kg) for sheep with only one offspring and 3.5 times for sheep with twins (NRC, 2007). Studies show that low water availability with a decreasing feed intake can cause pregnancy toxemia in sheep.

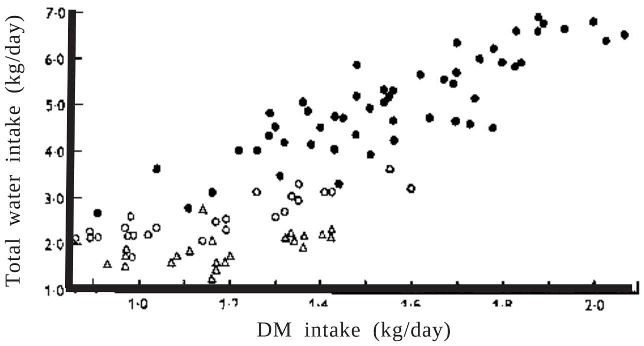

Figure 1 - Relation between total water intake and dry matter intake of non lactating and non pregnant sheep fed silage (●), pelleted hay (○) or hay with large particles (△). Adapted from Forbes (1968).

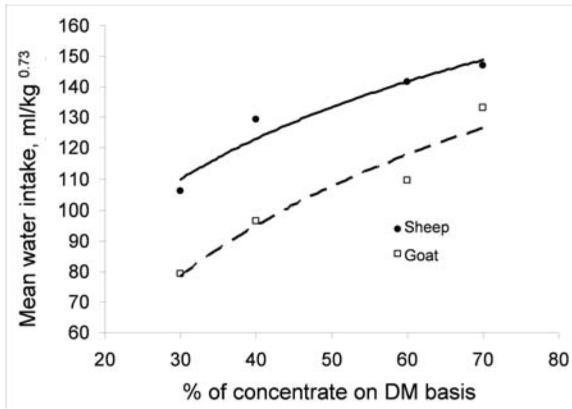

Figure 2 - Water intake by goats and sheep according to the percentage of concentrate in the diet. Adapted from Aganga (1992).

Santa Ines sheep presented higher water intake (3.95 L/animal/day) at 130 days of gestation in relation to the observed at 110 (3.21 L/animal/day) and 90 days of gestation (3.23 L/animal/day), because fetal development demands higher water volume to meet mother and fetus requirements, beyond the water required for tissue synthesis and mammary gland growth (Brito et al., 2007).

Factors that affect water intake

NRC (2007) theorizes that under standardized conditions the water use must be related to the energy metabolism instead of DMI. Thus, the relation between available water intake or total water requirement with the digestible energy intake or the metabolizable energy intake would be adequate. Aganga (1992) reported an increase in daily water intake as the percentage of concentrate increased in the diet of sheep and goats (Figure 2). However, Ferreira et al. (2002) observed smaller water intake for goats and sheep fed higher energy levels in the diets.

In Brazil Neiva et al. (2004) and Ribeiro (2006) corroborate with these premises working with sheep and goats, respectively. In both researches the high intake of dry matter and energy resulted in greater water ingestions, independently of the species.

Exposure to high temperatures affects water use in two ways: dry matter intake may decline, but requirements for evaporative and cutaneous cooling increase (NRC, 2007). Luke (1987) described linear increase of water intake by sheep as the daily maximum temperature increased (Figure 3). In these researches, the higher temperatures coincided with the dry season of the year and the high DM level of the pasture.

Additionally, the temperature of the water ingested is also an important factor because water may become a thermal buffer in the rumen-reticulum protecting or changing the fermentation capacity and therefore affecting the microbial function.

Aganga (1992) studied the water use by sheep and goats in the North of Nigeria and observed significant differences ($P<0.01$) on several variables, such as water intake, expressed in L/kg of metabolic weight, that was higher in sheep than goats. In relation to age, older animals drank more water than the younger ones, because the older animals had larger body size and, consequently, required more water for proper digestion and feed utilization. And concerning goat sex, females tended to drink more water than males.

According to Ferreira et al. (2002), Merino Mutton sheep drunk 48% more water than Boer goats. Hadjigeorgiou et al. (2003) found a water intake for sheep 15% higher than goats. Lower water intake by goats has been observed when compared to sheep and other animals, because of the adaptation process of goats to situations of limited water availability. The adaptation is similar to camels, known for their ability to withstand long periods without water (Silanikove, 2000) and their greater ability to reduce water loss through evaporation and feces and to concentrate urine (Robertshaw, 1982).

Similarly, Alves et al. (2007) in a study conducted in the municipality of Petrolina, Pernambuco state, reported that sheep ingested higher amount of water than goats. Both species were seven months old from traditional production systems, with no defined breed and 25 kg of body weight at the beginning of the trial. While sheep ingested 3.42 L of water daily, goats ingested 2.31 L/day. The lower water intake by goats is probably due to the high water use, and because of lower water losses by transpiration, urine and feces.

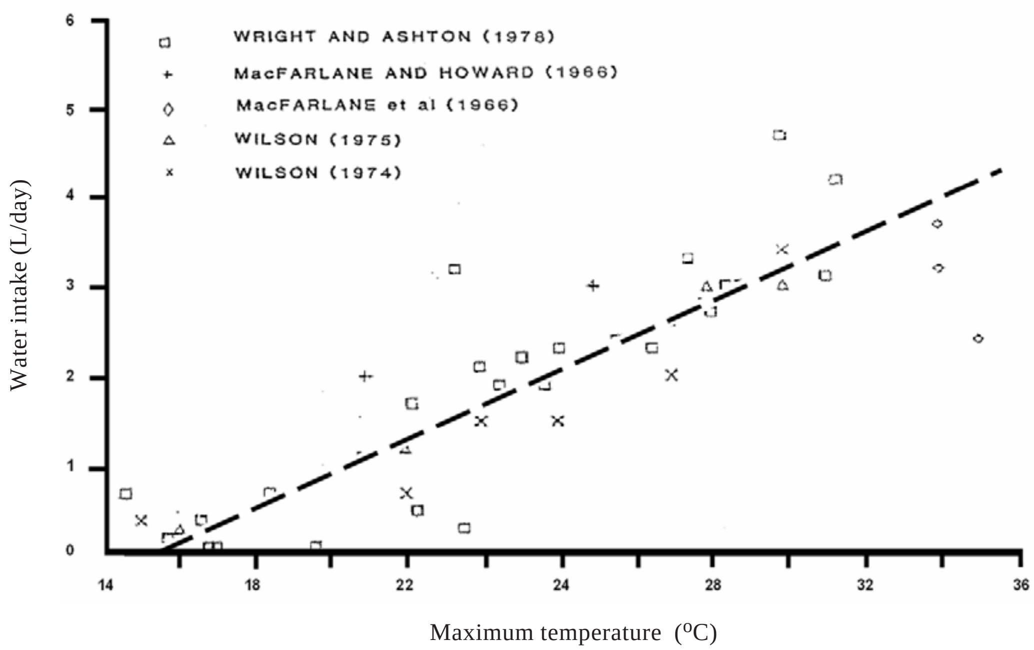

Figure 3 - Ratio between water intake and daily maximum temperature in sheep. Adapted from Luke (1987).

Aganga et al. (1986) examined the turnover of body water using the tritiated water method, and goats presented lower rates of turnover than sheep, thus goats are more resistant to water scarcity and present better adaptability to arid environments than sheep.

Besides factors related to the animal, water intake can also be affected by the arrangement of drinking troughs and the accessibility of the animal to points of water supply. This factor is very much important in the dry season, because that is when animals find low water availability in the forages and the access to points of water supply gets limited due to the arrangement of these points. Often, as occurs in the Brazilian semiarid, the water transportation to nearby locations where the animals are kept may be crucial for the best productive performances of the animals.

Types of diet and water intake

Animal diets are also determinant factors for water intake. As discussed latter, succulent feedstuffs can provide great part of the water required by the animals.

Costa et al. (2009) reported that lactating goats fed diet containing higher levels of in natural forage cactus in replacement with corn starch presented lower water ingestion with no effects on milk production. Similarly, Bispo et al. (2006) observed a decrease in water intake directly from drinking troughs as replacing forage cactus with elephant grass hay increased in sheep diet. Sheep fed diets with elephant grass hay as roughage drank 3.25 L/day while those fed diet containing forage cactus replacing elephant grass up to 56% of DM drank 0.44 L/day.

According to Araujo (2009), who replaced *in natura* forage palm with oldman saltbush and ground corn in the diet of Santa Ines sheep, the total water intake throughout the day ranged from 4.0 to 5.2 kg/animal/day with no effect on the total water ingested by the animals fed different diets. However, animals fed diets without oldman saltbush and ground corn drank 0.4 kg/day of drinking water, with water content of 4.1 kg/day, while those fed diets containing 82.7% of oldman saltbush hay replacing forage palm drank 3.2 kg/day, with water content of 2.0 kg/day. These authors noticed that water excretion ranged from 1.2 to 1.5 kg/day in feces and 1.1 to 2.3 kg/day in urine, concluding that the amount of water absorbed by the animal organism was similar, and source-independent.

Ribeiro (2006) related that Caninde and Moxoto goats, naturalized in Brazil ingested as average 6.22 L/day when fed diets *ad libitum* and 4.42 L when fed diets with restrained feed at 30% of *ad libitum*, evidencing that feed intake is important to determine the daily water intake of the animal and that water intake is also a determinant factor for feed intake.

Similar result was observed by Neiva et al. (2004) in a research conducted with Santa Ines sheep, in the municipality of Fortaleza, Ceara state. In this work sheep fed with higher levels of concentrate showed high water intake (4.20 L/day) and those fed diets with low levels of concentrate presented 3.00 L/day of water intake.

Water availability and restriction on the animal response

Water availability sometimes is limitant to herds in the arid and semiarid regions around the world. During the dry season, the animals ingest forage with low humidity level and low nutritional value and have irregular and limited access to potable water. Water intake is usually limited to once a day, when the animal has access to a water source. In many situations the transport of this water to the animals is necessary.

Hadjigeorgiou et al. (2000) reported that the low water availability for sheep happens in most productive areas in Greece, especially in the Summer, when most sheep are at the first half of gestation. They conducted a study with six Karagouniko sheep evaluating the effects of water restriction on nutrient intake and digestibility. The treatments were: (A) water fed *ad libitum* throughout the day; (B) water available for one hour a day and (C) 65% of water ingested *ad libitum*. The sheep from treatment (A) ingested more water, 181.9 g/kgBW$^{0.75}$, than those from the other treatments, which did not show significant difference among them, (B) 128.8 and (C) 117.5 g/kgBW$^{0.75}$. Dry matter intake and nutrient digestibility did not differ among the treatments, and it was concluded that water restrictions, usually observed during the dry season, had no effect on the nutrition of native breed of Greek sheep.

A study was carried out to evaluate the effect of water restriction on the performance of lactating Aardi goats at one of the driest regions of Saudi Arabia, with average temperature of 50^{o}C in the summer (Alamer, 2009). The experiment was divided into three periods (each one with 6 days): control, water restriction and dehydration. One group had 50% and another 25% of water restriction calculated in relation to the water ingested during the control period. Dry matter intake decreased in both groups, with similar values. Body weight loss, during water restriction, was similar in both groups (8 and 6%, respectively, for 50 and 25% water restriction groups). Milk production reduced from 20 to 18% for groups with 50 and 25% of water restriction, respectively. This author concluded that lactating Aardi goats under high environmental temperatures have high ability to withstand water restriction, but with a direct impact on animal performance.

Water and welfare of small ruminants

Water, among other resources, is essential for animals to adapt to adverse weather conditions, acting on the balance of thermal comfort and providing welfare.

Water use is affected in two ways when the animals are exposed to high temperatures: 1) decreasing dry matter intake and 2) increasing evaporation and skin cooling. Heat is dissipated through a set of physiological mechanisms from intracellular points of oxidation to the skin surface, where water can be lost by conduction, convection, radioactive processes and evaporation. The water vaporization is a powerful way to loose body heat in order to achieve thermoregulation at the thermoneutrality range, especially when the environmental temperature increases above the high critical temperature (NRC, 2007).

Brasil et al. (2000) worked with lactating Alpine goats under thermoneutral (TN) or thermal stress (ET) environments and noticed that the goats under thermal stress environment increased by 112% the daily water intake (462.41 mLD kgBW$^{0.75}$) in relation to the goats under thermoneutral environment (218.17 mLD kgBW$^{0.75}$). The higher water intake reflects the need of body cooling by conduction and replacement of the water evaporated by respiratory tract and skin.

Similarly, Candido et al. (2004) and Pompeu et al. (2009) observed higher water intake by sheep grazing pastures at the hottest hours of the day. Candido et al. (2004) observed this from 08:00 a.m. to 02:00 p.m., while Pompeu et al. (2009) recorded the highest interval of water intake from 11:00 a.m. to 02:00 p.m., showing that in the hottest periods of the day, which are also the periods of higher grazing activity, the “drinking water” can not be missing. McGregor (2004) made a review about water quality and supply for goats in Australia and gathered information about the best practices for supplying water for goats during drought. The observations showed that goats ingest less water than sheep when kept under shade, but Angora goats, which has long hair coat, drink more water than Merino sheep when kept without shade.

A study conducted by Neiva et al. (2004) evaluated the effect of environmental stress on performance and physiological responses of Santa Ines sheep. The authors found that animals kept under shade had significantly lower water intake (282 mL/kgBW$^{0.75}$) than those exposed to direct sunlight (353 mL/kgBW$^{0.75}$) under thermal stress. These results occurred probably due to the heat exchange between animal and environment as a response to the high water evaporation rate of the animal tissues.

These studies indicate that water is an important mechanism for thermoregulation in small ruminants. The animals seek for water especially during the hottest hours of the day and, in some cases, instead of places with shades, water may be chosen as a strategy for heat dissipation by the animal.

Water stocking rate

The term "stocking rate" is usually used to express the maximum number of animals grazing a pasture without degrading it. The same terminology can be attributed to the *water stocking rate*, which would express the amount of water needed to meet quality and quantity for a number of animals in a production system. However, few producers adopt a water program practice as management routine.

Araujo & Pereira (2007), evaluating data from Porto (2002) and Brito et al. (2005), estimated the *water stocking rate* for animal production systems in the municipality of Petrolina, Pernambuco state, in the Brazilian semiarid. The demand for water intake in a 1-year period corresponded to 1,826,825; 1,946,910; 858,480; 295,650; 302,220 and 26,061 liters of water for 143, 889, 392, 27, 92 and 350 heads of cattle, goats, sheep, service animals, pigs and poultry, respectively, therefore the total demand for water was 5,256,146 liters per year. However, only part of this demand was supplied by the existing water sources (ponds and pits), approximately 2,775 million liters / system considering the average water input of each system, there is a water deficit of 2,481 million liters, almost half the demand for water.

Considering the large number of animals in the communities and the insufficient water supply, measures must be taken in order to enhance the technologies for rainwater collection, groundwater use and efficient use of water.

Producers apply several strategies to collect water for animal use in the Brazilian semiarid: ponds, pits, small ponds and tanks. Among them, the rural tank presents advantages when compared to other methods. Brito et al. (2005) evaluated the use of rural tank with 16,000 liters of storage capacity.

The need of planning the volume of water support for animal production systems will increase according to the foresighted climate changes, and without this planning the producers will be subjected to cope with serious damage to their livestock production and also to the environment.

Water balance of sheep and goats

Water balance of the animal is the difference between water intake and water losses by the animal.

Regarding water losses, the animal can lose water through three main routes: urine, feces and transpiration. The urine is an important route for the excretion of products from metabolism that are soluble in water. Generally, when diets enriched with protein and minerals are offered to the animals, urine flow tends to be higher. A large amount of water can be lost via feces, and this is highly variable according to species. For example, goats and sheep feces contain lower water content (60 to 65%) when compared to cattle feces (70 to 75%). According to Aganga (1992), who compared the water balance of Yankasa sheep and Maradi goats in the northern Nigeria, the feed (hay) and water intake were higher for Yankasa sheep (Table 1). The goats produced feces with lower water concentration and had lower water loss through urine and transpiration, based on the metabolic weight, presenting better tolerance for arid and semiarid environments than sheep.

A study evaluating the effect of feed restriction (0, 30 and 60%) on water balance and nutrient use in Boer × Saanen goats was carried out by Texeira et al. (2006). The authors found a negative relation between dry matter intake (CMS) and water intake (CA). The results for dry matter intake were 102, 83, and 55 g/kgBW$^{0.75}$, for water intake were 303, 465 and 703 mL/kgBW$^{0.75}$, for water loss through feces were 62.0, 38.6 and 22.2 mL/day/ kgBW$^{0.75}$ and through urine were of 66.1, 314.6 and 563.2 mL/day/ kgBW$^{0.75}$, respectively for the levels of 0, 30 and 60% of feed restriction. The increase of water intake happened as an attempt of the animals to reduce the hunger sensation,

Table 1 - Water balance of Yankasa sheep and Madari goat in North Nigeria

Item	Sheep	Goat	SE
Average body weight, kg	25.56	20.16	0.25
Metabolic body weight, kgBW$^{0.75}$	10.95	8.96	0.08
Water intake, mL/kgBW$^{0.75}$/day	202.53a	152.4b	8.14
Water intake by ration, mL/kgBW$^{0.75}$/day	3.17	2.75	0.03
Metabolic water, mL/kgBW$^{0.75}$/day	19.02a	16.95b	0.36
Water lost by feces, mL/kgBW$^{0.75}$/day	16.08a	9.32b	0.84
Water lost by urine, mL/kgBW$^{0.75}$/day	45.60	42.00	2.07
Water lost by transpiration, mL/kgBW$^{0.75}$/day	162.40a	120.40b	6.74
Average daily urine production, mL	501.1	382.9	9.16
Daily water intake, Ml	2,218	1,364	68.79
Daily hay intake, g	500,0	375.0	-
Average daily feces production, g	362.1	208.8	10.92

SE = standard error.
Source: Aganga (1992).

through ruminal fulfillment with water stimulating ruminal mechanoreceptors and not due to an increase in water requirement of animals.

Tosto et al. (2010) evaluated the water balance of goats fed diets with forage palm and concentrate. The increase in levels of oldman saltbush hay in the diets resulted in crescent linear intake of water. The total water intake showed quadratic effect just as the dietary water intake. The diet with 74.9% of forage palm and 8.4% of oldman saltbush hay presented the lower water balance (1.90 kg/day) and low water intake (1.60 kg/day) per kg of DM intake (Table 2). The authors concluded that the inclusion of oldman saltbush in the diets of goats increased the water intake and the water balance, while the use of forage palm decreased these variables.

Water quality

Water quality is presented by a set of physical, chemical and biological characteristics. There is a set of criteria and standards for water quality that changes according to the purpose (human watering, domestic use, animal watering, recreation, industrial use, agricultural use, environmental maintenance and others).

Water quality is extremely important for the animal, not only for ingestion (and consequently for feed intake and productive performance), but also for animal health because water can be an important vehicle for chemical, physical and biological contaminants, which should be avoided due to the damage they cause to animals.

Some pathogenic microorganisms that are important as biological contaminants of water: bacteria (*Campylobacter jejuni*, *Escherichia coli*, *Salmonella* - 1700 spp.), virus (adenovirus - 31 types, enteroviruses - 71 types, rotavirus), protozoa (*Balantidium coli*, *Entamoeba histolytica*, *Giardia lamblia*), and helminths (*Ancylostoma duodenale*, *Ascaris lumbricoides*, *Dracunculus medinensis* and others), which use water as vehicle and once they are ingested and installed in the animal organism, serious damage can happen.

Wilms et al. (2002) evaluated three sources of water supply for animals: 1 - clean, fresh water from rivers, streams or wells, 2 - water captured in tank or water fountains, provided in drinking troughs and 3 - direct access of the animals to collection tanks, and observed higher water intake of animals that received clean and fresh water from rivers, streams and ponds, followed by the water captured and provided in troughs and finally by the water ingested directly at the collection tank.

National Research Council (NRC, 2007) described other chemical contaminants like salts, toxins produced by algae and microorganisms, beyond heavy metals, polychlorinated biphenyls and other chemicals from agricultural or industrial practices that may result in changes of water intake by goats and sheep and even affect their health.

Monitoring parameters related to water quality can be quickly performed on site with the use of kits, such as the determination of pH values. However, in most situations water samples must be collected and sent to laboratories, following their recommendations for collection, storage and shipping because some characteristics of the water are determined by laboratory tests.

Salinity

Salinity is the total amount of mineral salts dissolved in water. The animal tolerance to salinity changes according to species, age, water need and physiological conditions. Salts that are important water contaminants: carbonates,

Table 2 - Average daily values of water intake, water losses and water balance, their respective coefficient of variation (CV), coefficient of determination (R^2) and regression equations (RE) of crossbred Boer fed increasing levels of old man saltbush hay

Variable	Old man saltbush hay (%)				CV	RE	R^2
	8.4	18.8	31.2	48.3			
Total dry matter intake, kg/day	0.43	0.83	0.96	0.93	27.2	$\hat{Y} = 0.06 + 0.05X - 0.0007X^2$	0.53*
Water intake , mL	0.69	1.59	2.52	3.50	20.7	$\hat{Y} = 0.07 + 0.18X$	0.87*
Water intake by ration, mL/day	2.35	2.72	2.23	0.41	33.3	$\hat{Y} = 1.89 + 0.08X - 0.0023X^2$	0.70*
Total water intake, mL/day	3.05	4.31	4.29	3.92	19.8	$\hat{Y} = 1.99 + 0.16X - 0.0024X^2$	0.32*
Water intake per kg of DM intake	1.60	3.46	3.75	2.92	50.6	$\hat{Y} = -0.22 + 0.26X - 0.0041X^2$	0.26**
Water losses by feces, mL/day	0.33	0.53	0.65	0.38	38.7	$\hat{Y} = 0.08 + 0.04X - 0.0006X^2$	0.29*
Water losses by urine, mL/day	0.81	0.88	1.00	0.78	38.0	$\hat{Y} = 0.87^{NS}$	-
Total water losses, mL/day	1.15	1.41	1.65	1.16	36.2	$Y = 1.34^{NS}$	-
Water balance, mL/day	1.90	2.90	3.10	2.76	21.4	$\hat{Y} = 1.18 + 0.11X - 0.0016X^2$	0.35**

NS – not significant; *P<0.05; **P<0.01; Adapted from Tosto et al. (2010).

bicarbonates, sulfates, nitrates, chlorides, phosphates and fluorides. Water with less toxic salts can cause an increase in water intake.

Salinity is expressed as parts per millions (ppm) or as milligrams per liter (mg/L). The level of water salinity is frequently expressed as “Total Dissolved Solids” (TDS). And it seems that there is no difference if the total amount of dissolved salts or dissolved solids is composed of a single salt or a number of salts (Boyles, 2009).

In a classic study Pierce (1957) offered water with four levels of sodium chloride (0, 1.0, 1.5 and 2.0%) for sheep during 15 months and observed water intake of 2.0, 3.0, 4.0 and 3.0 L/animal/day. The author reported that the ingestion of water with up to 1% of sodium chloride did not affect feed intake or growth performance of animals, but from 1.5 to 2% lower feed intake and weight gain were observed.

Wilson (1966) observed similar behavior when evaluated the effect of different levels of salt in the diets and water fed Merino sheep. Water intake increased of animals fed diets with high salt concentration (2%), due to the large volume of water needed for salt excretion.

Animals can be adapted to drink saline water, however, a gradual addition is recommended because the abrupt change can result in negative influence on feed and water intake. McGregor (2004) reported that goats can accept saline water with up to 12,500 mg TDS/L, when compared to potable water. These animals can ingest saline water with levels up to 9,500 mg TDS/L, with no effects on feed intake, however higher levels decrease feed intake. The time needed for goats to adapt to water with high levels of salt is unknown.

Runyan & Bader (1994) reported that the supply of water with electrical conductivity (salt content) from 8.0 to 11.0 dS/m should be limited to ruminants, including goats and sheep. Water with conductivity higher than 11.0 dS/m are considered as high risk to young animals, pregnant and lactating, whereas higher than 16.0 dS/m can not be supplied to any animal specie.

Another criterion of saline/brackish water use for the animal watering is reported by Bagley et al. (1997). These authors found that values of 1,000 ppm of total dissolved salts are considered low, and the water can be fed to any animal specie. However, concentrations of total dissolved salts in water ranging from 1,000 to 4,999 ppm are satisfactory for sheep and cattle without any effect on the productive performance, but may cause temporary diarrhea or have poor acceptance by non-adapted animals. Water with levels ranging from 5,000 to 6,999 ppm of total dissolved salts can also be used for sheep and cattle, but its ingestion by animals in advanced stages of pregnancy or lactation should be avoided.

Climate changes, water and small ruminants

Nardone et al. (2010) described the effects of climate changes on livestock, according to the theory of global warming. Although the adverse effects of global warming will not happen everywhere because if temperature increases in the cold or warm climates regions, these regions would host a new group of animal and plant species. Still a high increase in air temperature is forecasted for several world regions, and in this case, semi-arid regions like Brazil would become dry, affecting water availability by decreasing rainfall and increasing evaporation, with consequent effects on crops and livestock production.

The environment warming may affect production (animal growth, weight gain, meat quality, milk and eggs), reproductive performance, metabolism and animal health, because of the direct effects caused by high temperatures, as previously discussed, and of the indirect effects due the reduced water and food availability. In a semiarid-arid transition region, the desertification process reduces the stocking rate of pastures and forages. Thus the strategy for livestock will be to use crops with higher water use efficiency; to optimize forage productivity with water and soil management; to improve strategies to capture rain water; and to enhance the ability of animals to withstad environmental stress.

Goats and sheep may be a productive alternative to address and mitigate potential impacts of climate change because they have great ability to adjust to adverse environmental conditions. These animals have physiological mechanisms that in most circumstances promote their adaptation to most hostile environments, ensuring lower losses in performance, maintaining good reproductive rate, good resistance to diseases and low mortality rates. The rearing success of sheep and mainly goats in the arid and semiarid regions corroborate with this fact.

Water productivity on small ruminant production

According to National Geographic (2010), trillion liters of virtual water are transferred in the global trade of agricultural products, something comparable to the volume of water that flows annually through the Congo River. The main exporting regions for meat and cereals, such as Brazil, are the greatest exporters of virtual water. To calculate the virtual water for different meats, the amount ingested by the animals and the amounts used for feedstuffs cultivation, and cleaning of animal waste and facilities must be considered. Thus if 1 kg of bovine boned meat is considered, 15,497 L of water would be necessary. For swine and poultry meats, respectively, it would be necessary 6,309 and 3,918 liters of water. It is estimated that the water efficiency of utilization must double in the next 20 years to feed the population.

Water productivity is usually defined as the produced agricultural products: consumed water ratio. It provides a reliable measure of the agricultural system ability to convert water into feedstuff (Kijne et al., 2003). The livestock water productivity (LWP), specifically, is the relation among the net benefits of animal origin, including products and services, and the water used and degraded during their production (Peden et al., 2007, cited by Descheemaeker et al., 2010). It is represented by the equation:

$$WP_L = \frac{P_L + S_L}{W_{DP} + W_{DG} + W_{DV}}$$

where: $P_L + S_L$ are livestock products and services; W_{DP}, W_{DG} and W_{DV} are quantities or value of depleted, degraded and devalued water.

A statistical model of water use in the beef cattle production was developed in the United States by Beckett & Oltjen (1993). This model included the ingested water by several animal classes, the water used for the irrigation of crop consumed by the animals, the water used in the forage irrigation and the water used in the commercialization process. The model estimated a water requirement of 3682 L per kilogram of boned beef for meat production that was below the value estimated by the National Geographic (2010). The model was most sensitive to the dressing percentage and percentage of boned yield in carcasses of feedlot cattle (62 and 66.7, respectively). The change of 10% in each parameter resulted in a corresponding value of 8.6% of water required for beef production. Supposing 10% of increase in the number of animals, the model indicates that it is possible to decrease the amount of water per kilogram of boned meat by 5.2%. The authors also related that changes on irrigated pasture management would be efficient to decrease water use.

Surveys conducted by Embrapa Tropical Semiarid, using a cultivation area of Tifton 85 continuously grazed by sheep in the finishing phase, observed a degraded area of 18,250 m^3/ha/year, which added to the amount of annual rainfall (4,800 m^3/ha/year) resulted in total water amount of 23,050 m^3/ha/year. Then 659.6 L of water would be necessary to produce 1 kg dry matter of forage. In the same season 3,200 kg of meat/ha/year were obtained. Water intake by the animals throughout the year was 61,320 L, approximately 2 L/animal/day in average. Thus, 0.139 kg of meat/m^3 of water were obtained and approximately 7,220 L of water was needed to produce 1 kg of meat.

Under rainfed conditions, considering the forage buffel grass yield cultivated at Embrapa Tropical Semiarid during four years, 111-231 kg meat/ha/year was obtained with cattle. When the water ingested by the animals was not recorded, amounts from 0.022 to 0.046 kg of meat/m^3 of water were found and then 21,645 to 45,045 L of water were needed to produce 1 kg of meat. Both situations showed different results, because in the first one the irrigation resulted in higher meat yield per liter of water in relation to the second one, under rainfed conditions. However, under rainfed condition, the total water volume was much lower than the volume used in the irrigated area. In the presented situations, water can be spent efficiently to produce more feed; or lower water volumes can be used in livestock production resulting in low yields but then water may be applied to other uses.

According to Descheemaeker et al. (2010), interventions are needed to increase water productivity and should be grouped into three categories: water, feedstuffs and animal management. Strategies for improving LWP include feedstuff quality and obviously a careful choice of different diet types and pasture management practices. Water management for greater LWP includes water conservation, through the processes of management and integration of animal production systems and the use of water for irrigation. Researches aiming to identify gap in methodologies to quantify water productivity at different scales and to improve integration between the agricultural sectors are necessary.

Finally it should be emphasized that the concept of water productivity for livestock production is relatively new and the studies conducted in the world and particularly in Brazil are recent and few. This theme, of course, will be increasingly present in classrooms and research institutions, because the current society requires changes of concepts and understand that water is a scarce resource. Professionals in the area of animal science must embrace this cause and generate technologies to improve water productivity indices for products of animal origin.

Final Considerations

Water is the simplest of all substances present in food, however, to manage it is not so simple. It is an essential nutrient in the animal life and should be considered vital at all rearing phases. Goats and sheep, throughout their generations, were subjected to adaptive processes that increased the efficiency of water use. Despite the importance of water and the understanding of its effects on the animal response, there is still few information about this nutrient in Brazil. Further studies and the generation of new technologies for water use are indispensable, considering the climate changes forecast and thus improving the water productivity indices in livestock production.

References

AGANGA, A.A.; UMUNNA, N.N.; OYEDIPE, E.O. et al. Breed differences in water metabolism and body composition of sheep and goats. **The Journal of Agricultural Science**, v.113, p.255-258, 1989.

AGANGA, A.A. Water utilization by sheep and goats in northern Nigeria. **Revista Mundial de Zootecnia**, v.73, 1992.

ALAMER, M. Effect of water restriction on lactation performance of Aardi goats under heat stress conditions. **Small Ruminants Research**, v.84, p.76-81, 2009.

ALVES, J.M.; ARAÚJO, G.G.L.; PORTO, E.P. et al. Feno de erva-sal (*Atriplex nummularia* Lindl.) e palma-forrageira (*Opuntia ficus* Mill.) em dietas para caprinos e ovinos. **Revista Científica de Produção Animal**, v.9, n.1, p.43-52, 2007.

ARAUJO, G.G.L.; PEREIRA, L.G.R. Captação de água de chuva: consumo animal In: SIMPÓSIO DE CAPTAÇÃO E MANEJO DE ÁGUA DE CHUVAS, 6., 2007, Belo Horizonte. **Anais...** Belo Horizonte: ABCMAC-UFMG, 2007.

ARAÚJO, G.G.L.; BADE, P.L.; MENEZES, D.R. et al. Replacing cassava meal by forage cactus meal in sheep diets **Revista Brasileira de Saúde e Produção Aninal**, v.10, n.2, p.448-459, 2009.

ARAUJO, R.F.S.S. **Avaliação nutricional e função renal de ovinos alimentados com feno de erva-sal (*Atriplex nummularia* L.) e farelo de milho em substituição a palma forrageira (*Opuntia fícus-indica* Mill.)**. 2009. 47f. Dissertação (Mestrado em Zootecnia) - Universidade Federal Rural de Pernambuco, Recife.

BAGLEY, C.V.; AMACHER, J.K.; POE, K.F. **Analysis of water quality for livestock**. Logan: Utah State University, Cooperative Extension, 1997. 7p.

BECKETT, J.L.; OLTJEN, J.W. Estimation of the water requirement for beef production in the United States. **Journal of Animal Science**, v.71, p.818, 1993.

BISPO, S.V.; FERREIRA, M.A.; VÉRAS, A.S.C. et al. Efeito da substituição do feno de capim-elefante por palma-forrageira sobre o consumo e parâmetros fisiológicos de ovinos. In: ZOOTEC 2006. **Anais...** ZOOTEC, 2006.

BOYLES, S.; WOHLGEMUTH, K. FISHER, G. et al. **Livestock and water**. North Dakota State University: Extension Service Bulletin AS-954. 1988.

BRASIL, L.H.A.; WECHESLER, F.S.; BACCARI JR., F. et al. Thermal stress effects on milk yield and chemical composition and thermoregulatory responses of lactating alpines goats. **Brazilian Journal of Animal Science**, v.29, n.6, p.307-321, 2000

BRITO, L.T.L.; PORTO, E.R.; SILVA, D.F. et al. **Água de chuva para consumo animal**: estudo de caso com caprinos. In: SIMPÓSIO BRASILEIRO DE CAPTAÇÃO E MANEJO DE ÁGUA DE CHUVA, 5., 2005, Teresina. **Anais...** Teresina: ABCMAC, 2005.

BRITO, T.S.; VIANA, M.H.; FIGUEIREDO, F.O.M. et al. Consumo de água e sal mineral de ovelhas da raça Santa Inês gestantes submetidas a dois manejos nutricionais. In: CONGRESSO BRASILEIRO DE ZOOTECNIA, 2007. **Anais...** 2007. (CD-ROM).

CÂNDIDO, M.J.D.; BENEVIDES, Y.I.; FARIAS, S.F. et al. Comportamento de ovinos em pastagem irrigada sob lotação rotativa com três períodos de descanso. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 2004, Campo Grande. **Anais...** Campo Grande: Sociedade Brasileira de Zootecnia, 2004.

COSTA, R.G.; BELTRÃO FILHO, E.M.; MEDEIROS, A.N. et al. Effects of increasing levels of cactus pear (*Opuntia ficus-indica L*. Miller) in the diet of dairy goats and its contribution as a source of water. **Small Ruminant Research**, 2009 (in press).

COSTA, R.G.; QUEIROGA, R.C.R.E.; PEREIRA, R.A.G. Influence of feed on the production on quality of goat milk. **Brazilian Journal of Animal Science**, v.38, p.307-321, 2009 (supl. especial).

DESCHEEMAEKER, K.; AMEDE, T.; HAILESLASSIE, A. Improving water productivity in mixed crop-livestock farming systems of sub-Saharan Africa. **Agricultural Water Management**. v.97, p.579-586. 2010.

ESMINGER, M.E.; OLDFIELD, J.L.; HEINEMANN, J.J. **Feeds and nutrition** 2.ed. Clovis: Esminger Publishing, 1990. 1552p.

FORBES, J.M. The water intake of ewes. **British Journal Nutrition**, v.22, p.33-43, 1968.

GASTALDELLO JR., A.L.; PIRES, A.V.P.; SUSIN, I.S. et al. Performance and carcass characteristics of feedlot lambs fed high grain diets with buffer compounds. **Brazilian Journal of Animal Science**, v.39, n.3, p.556-562, 2010.

HADJIGEORGIOU, I.; DARDAMANI, K.; GOULAS, C. et al. The effects of water availability on feed intake and digestion in sheep. **Small Ruminants Research**, v.37, p.147-150, 2000.

LUKE, G.J. **Consumption of water by livestock**. s.l.: Department of Agriculture Western Australia, 1987. 22p. (Resource Management Technical Report, 60).

McGREGOR, B.A. Water intake of grazing Angora wether goats and Merino wether sheep. **Australian Journal of Experimental Agriculture**, v.26, p.639-642, 1986

McGREGOR, B.A. Water quality and provision for goats. Australian Government. **Rural Industries Research and Development Corporation**. 19p. 2004.

MEDINA, F.T.; CÂNDIDO, M.J.D.; ARAÚJO, G.G.L. et al. Manioc silage associated with energy sources on feeding goats: intake and digestibility. **Acta Scientiarum.Animal Sciences**, v.31, n.3, p.265-269, 2009.

NARDONE, A.; RONCHI, B.; LACETERA, M.S. et al. Effects of climate changes on animal production and sustainability of livestock system. **Livestock Science**. (doi;10.1016D j.livsi.2010.02.01). 2010.

NATIONAL GEOGRAPHIC. **Água**: o mundo tem sede. Rio de Janeiro: Abril, 2010. 150p.

NATIONAL RESEARCH COUNCIL – NRC. **Nutrient requeriments of dairy cattle**. 6.rev.ed. Washington, D.C.; 2001. 381p.

NATIONAL RESEARCH COUNCIL - NRC. **Nutrient requeriments of small ruminants**: sheep, goats, cervids, and new world camelids. Washington, D.C.; 2007. 384p.

NEIVA, J.N.M.; TEXEIRA, M.; TURCO, S.H.N. et al. Effects of environmental stress on physiological parameters of feedlot sheep in the Northeast of Brazil. **Brazilian Journal of Animal Science,** v.33, n.3, p.668-678, 2004.

OLIVEIRA, J.B.; PIRES, A.J.V.; CARVALHO, G.G.P. et al. Industrial by-products in elephant grass silage for dairy goats: intake, nutrient digestibility and milk yield. **Brazilian Journal of Animal Science**, v.39, n.2, p.411-418, 2010.

OSÓRIO, J.C.S.; OSÓRIO, M.T.M.; SAÑUDO, C. Sensorial characteristics of sheep meat, **Brazilian Journal of Animal Science**, v.38, p.292-300, 2009 (supl. especial).

PEDEN, D.; TADESSE, G.; MISRA, A.K. **Water and livestock form human development**. Disponível em: http://

www.iwmi.cgiar.org/ assessment/Water for Food Water for Life/ Chapters/ ChapterLivestock.pdf Acesso em: 10/3/2010.

PIERCE, A.W. Studies of salt tolerance of sheep. I. The tolerance of sheep for sodium chloride in the drinking water. **Australian Journal of Agricultural Research**, v.8, n.6, p.711-722, 1957.

PLUMB, S.C. Water consumption by sheep. **Journal of Animal Science**. p.109-112, 1927.

POMPEU, R.C.F.F.; ROGÉRIO, M.C.P.; CÂNDIDO, M.J.D. et al. Comportamento de ovinos em capim-tanzânia sob lotação rotativa com quatro níveis de suplementação com concentrado. **Brazilian Journal of Animal Science**, v.38, n.2, 374-383, 2009.

PORTO, E.R. **Diagnóstico agropecuário do município de petrolina**. Petrolina: Prefeitura Municipal de Petrolina, 2002. 55p.

RIBEIRO, V.L.R.; BATISTA, A.M.V.; CARVALHO, F.F.R. et al. Ingestive behavior of Moxoto and Caninde goats submitted to *ad libitum*and restricted feeding. **Acta Scientiae.Animal Science**, v.28, n.3, p.331-337, 2006.

RUNYAN, C.; BADER, J. Water quality for livestock and poultry. In: ___ **Water quality for agriculture**. Rome: FAO, 1994. 186p. (Irrigation and Drainage Papers, 29).

SILANIKOVE, N. The physiological basis of adaptation in goats to harsh environments. **Small Ruminant Research**, v.35, n.6, p.181-193, 2000.

SILVA, A.M.A.; SANTOS, E.M.S.; PEREIRA FILHO, J.M.P. et al. Body composition and nutritional requirements of protein and energy for body weight gain of lambs browsing in a tropical semiarid region. **Brazilian Journal of Animal Science**, v.39, n.1, p.210-216, 2010.

TEXEIRA, I.A.M.A.; PEREIRA FILHO, J.M.; MURRAY, P.J. et al. Water balance in goats subjected to feed restriction. **Small Ruminant Research**, v.63, p.20-27, 2006.

TOSTO, M.L.; ARAÚJO, G.G.L.; PEREIRA, L.G.R. et al. Balanço hídrico de caprinos 1/2 sangue Bôer alimentados com feno de erva-sal, palma forrageira e concentrado. In: REUNIÃO ANUAL DA SOCIEDADE BRASILEIRA DE ZOOTECNIA, 2010, Salvador. **Anais...** Salvador: Sociedade Brasileira de Zootecnia, 2010.

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION - UNESCO. **World water development reports 2** – Water, a shared responsibility. Paris: Berghahn Books; New York, 2006.

WILSON, A.D. The tolerance of sheep to sodium chloride in food or drinking water. **Australian Journal of Agricultural Research**, v.17, n.4, p.503-514, 1966.

WILMS, W.D.; KENZIE, O.; MCALLISTER, T.A. et al. Effects of water quality on cattle performance. **Journal of Range Management**, v.55, p.452-460, 2002.