



Response of Small Ruminants to Water Stress in Arid and Semi-Arid Regions: A Review

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Abstract

Small ruminants are of social and economic importance due to their great ability to adapt to adverse environmental conditions, and efficient use of water is a major economic activity in the arid and semiarid regions of the world. Therefore, this paper aimed to review the effects of water stress on the adaptability of small ruminants in arid and semiarid regions. Many mechanisms work against water stress in small ruminants including behavioural, morphological, physiological, and biochemical mechanisms. Drinking behaviour in sheep and goats revealed interesting differences in the behavioural strategies between both species. The drinking behaviour was defined as follows: frequency of drinking and duration (time in minutes when the animal was actively involved in the ingestion and swallowing of water). Morphological characteristics such as body shape and size help reduce heat loads and minimize water losses; it is noted that goat breeds of arid and semi-arid regions are relatively smaller than exotic breeds. Changes in rectal temperature (OF), pulse rate (no. / min.), and respiration rate (no./min.) indicated the adaptability of the animals to increased thirst periods. Dehydration due to the thirst period provoked physiological mechanisms in the body in a manner that helped the animals to survive. Biochemical parameters like blood serum hormones, mineral profile, metabolites, and liver-kidney function were not affected by water restriction in goats so goats may survive at 50% restriction of water without affecting physiological indices and then their production. Furthermore, lower body weight gain and variation in physiological response and blood parameters in water-restricted animals reflect different adaptive strategies to counteract water restriction, as water restriction can increase stress in animals. Identification of breeds that show high adaptability to arid and semi-arid regions with an acceptable level of productivity is also important.

Keywords: Adaptability, Stress, Water

Introduction

Small ruminant production is an important economic activity in the arid and semiarid regions of the world, which are characterized by water scarcity and fluctuating precipitation under the effect of global warming and become even more irregular and water availability more limited. In the changing scenario of climate change, thermal stress, along with feed and water scarcity, are the main predisposing factors to the low productivity of small ruminants in hot semiarid environments (Sejian *et al.*, 2012). Water scarcity during summer is a serious regional problem, particularly in arid and semi-arid regions (Chedid *et al.*, 2014). During summer, good quality drinking water is reduced for all species. Drinking water is often a limiting factor for livestock in grazing areas of the semiarid (Najed *et al.*, 2014a; Casamassima *et al.*, 2008). However, the amount of water required by Sheep and Goat is depending on body metabolism, ambient temperature, stage of production, size, wool covering, amount of feed consumed and feed composition, etc. For example, goats adapt to water shortages by limiting dry matter intake. Goats also save water by limiting respiration and storing water in their extracellular spaces when water is abundant to ensure the availability of sufficient water for metabolism during a water deficit (Silanikove, 2000). This is important since it is widely known that sub-Saharan regions are facing a water crisis (Mabhaudhi *et al.*, 2013; News24, 2014).

Hence, the selection of adapted animal breeds is very important for sustainable animal production in this challenging environment. The breeds of this region have developed an adaptive capacity to survive in these adverse conditions. Reports (Najed *et al.*, 2014b; Chedid *et al.*, 2014) are available that small ruminant breeds in hot arid, and semi-arid regions may survive up to 1 week with little or even no water. Water shortage affects the physiological homeostasis of an animal, leading to loss of body weight, low reproductive performance, and decreased resistance to diseases (Barbour *et al.*, 2005). Variation in tolerance to water deprivation is observed in different breeds; however, indigenous small ruminants can thrive despite extreme temperatures and limited water through their behavioral adaptations in combination with both morphologic and physiological adaptations (Cain *et al.*, 2005). This challenging situation causes a wide array of responses, physiological and biochemical responses in small ruminants with a negative impact on production, immunity, and welfare (Barbour *et al.*, 2005; Jaber *et al.* 2011). Therefore, the objective of this review is to highlight the behavioral, morphological, physiological, and biochemical changes in small ruminants when faced with water stress in an arid and semi-arid region.

Literature Review

General Characteristics of Small Ruminants in Arid and Semi-Arid Regions

Small ruminants in the Middle East and Africa region are mostly reared under extensive and traditional pastoral farming systems, centuries-old, relying on natural pastures and mobility to secure water and feed year-round. Giger-Reverdin and Gihad (1991) reported that goat water requirement for maintenance in temperate climates is 107ml/kg BW^{0.75}; they also indicated that the water requirements at different ambient temperatures, based on previous work, range between 3.15 kg/kg DM (at 23 ° C) and 4.71 kg/kg DM (at 35 ° C). Most small ruminants respond to water stress by decreasing their food intake, resulting in a reduction in reduction due to water and body mass loss (Chedid *et al.*, 2014). They are well-adapted to this climate and can thrive under these stressful conditions (Naqvi *et al.*, 2013). Although small ruminants in hot arid and semi-arid regions can survive up to one week with little or even no water, water deficiency has been shown to affect animal physiological homeostasis, leading to loss of body weight, low reproductive rates, and decreased resistance to diseases (Barbour *et al.*, 2005).

Both the availability and salinity of water influence small ruminants' productivity. However, sheep breeds differ in their capacity to overcome water limitations; experiments show a variety of results. Yankasa sheep survived 5 days of water restriction but with several physiological changes (Aganga *et al.*, 1989; Igbokwe, 1993). Jaber *et al.* (2004) concluded that Awassi females can withstand more than one month of watering every 2 days without significant changes, while a regime of watering once every five days causes important physiological perturbations. Australian Merino sheep survived 10 days without water (Macfarlane, 1964), and desert bighorn sheep remained under water deprivation for up to 15 days, while Barki sheep in Egypt did not endure 3 days without drinking (Farid *et al.*, 1984). Furthermore, Malpura ewes can adjust their physiochemical response and reproduction up to 20% of water restriction during hot summer (Kumar *et al.*, 2016).

Climate Change, Water Resources, and Livestock System

Climate change mostly affected developing countries, in particular among populations referred to as subsistence or smallholder farmers (Morton, 2007; Madzwamuse, 2010). Furthermore, small farm sizes, low technology, and low capitalization are likely to increase the vulnerability of livestock production. Water supplies from rivers, lakes, and rainfall are threatened by climate change which reduces water availability for livestock production. Projected twenty-first-century changes in air temperature and precipitation patterns due to climate change may alter the availability of water leading to new challenges for water supply planning and management in many regions throughout the world (Bates *et al.* 2008; Hunt and Watkiss 2011). Regions with arid and semi-arid climates could be sensitive to even minor and insignificant changes in climatic characteristics. Climate change in Africa will have an overall modest effect on future water scarcity relative to other drivers, such as population growth, urbanization, agricultural growth, and land-use change (Notter *et al.*, 2012; Tshimanga and Hughes, 2012).

Approach to Water Challenges in Small Ruminants

Water scarcity is a global topical issue, particularly in Sub-Saharan regions (Mabhaudhi *et al.*, 2013; News24, 2014). Water sites are largely dispersed due to drought (Silanikove, 2000). Therefore, water points are available; they can contain considerable amounts of dissolved solids that may reduce the quality of water resources for small ruminants (McGregor, 2004a; Alamer, 2009; Masikati, 2010). Such conditions could be stressful to small ruminants and impact negatively their productivity since they depend on available input resources to meet daily nutritional requirements. In conditions where water resources are poor in quantity and quality, small ruminants particularly goats tend to adapt to their natural water-saving mechanisms (Alamer, 2009). Under such environmental conditions, the use of indigenous adapted breeds is relevant. Such characteristics help to ensure the conservation of goat genotypes capable of withstanding water scarcity. Therefore, farmers that keep small ruminant conditions where water resources are scarce need to understand the effects of water deprivation, water restriction, and water salinity.

Water Deprivation

Goats withstand water scarcity for days, as water points tend to be far from grazing areas under communal production systems (Misra and Singh, 2002). For example, Tswana goats and the black Bedouin goats have been reported to withstand three- and four-day periods without water, respectively (Maltz *et al.*, 1984; Adogla-Bessa and Aganga, 2000). When water resources become available, goats tend to consume water to overcome excessive thirst rather than to meet their daily water requirements (Adogla-Bessa and Aganga, 2000; Prasetiyono *et al.*, 2000). By so doing, goats counteract water deprivation by storing water in extracellular spaces in the rumen. This is done to ensure metabolic water is available for the next periods of water deprivation. Water-saving mechanisms are beneficial to goats in that they efficiently utilize the available feed resources using the available metabolic water stored in the rumen. Therefore, subjecting indigenous goats in sub-Saharan Africa to such conditions can help devise means of adaptation to water scarcity.

Table 1: Intake, growth, and nutritional status of indigenous goats subjected to water deprivation

Goat Productivity	Water Deprivation (in hours)					Source
	0	24	48	72	96	
Intake	0	24	48	72	96	
Water intake (mL/d)	3200	1546	1252	1022	-	Adogla-Bessa and Aganga (2000)
Feed intake (g DM/day)	762	743	742	758	-	Adogla-Bessa and Aganga (2000)
Body weight (kg)	20.0	20.0	20.3	20.5		Abdelatif <i>et al.</i> (2010)
Glucose (mg/dl)	50.8	51.5	47.0	50.0	57.6	Eltayeb (2006)
Creatine (mg/dL)	0.63	0.67	0.60	0.68	-	Abdelatif <i>et al.</i> (2010)
Urea (mg/dl)	21.42	22.0	23.0	24.0	25.0	Eltayeb (2006)
Cholesterol (mg/dl)	119.2	-	-	-	-	Ihedioha and Agina (2013)

Water Restriction

The inaccessibility and unavailability of sufficient water for goats daily remain a topical issue. The available water points do not meet the daily requirements of the goats, which requires the that need goats to adjust their metabolic water requirements (Alamer, 2009). Water scarcity is high during dry seasons, resulting in possible dehydration in goats. In such situations, goats minimize water losses resulting in the increased capability to withstand water deficit (Maltz *et al.*, 1984; Silanikove, 2000). When water is then made available, goats tend to consume water to ensure

the maintenance of sufficient water in the rumen. The availability of sufficient metabolic water in the rumen is necessary for the microbial community to help degrade the feed ingested by the goat. Therefore, goats must maintain the rumen environment even when the water supply is limited, as this helps ensure maximum utilization of feed resources. Several studies about water restriction on various goat breeds such as the West African Dwarf and Red Sokoto have been explored to measure their adaptability to water stress (Alamer, 2009; Abioja *et al.*, 2010; AlRamamneh *et al.*, 2012).

Table 2: Intake, growth, and nutritional status of indigenous goats subjected to water restriction

Goat Productivity	Water Restriction (%)				Source
Intake	20-40	40-60	60-80	80-100	Abioja <i>et al.</i> (2010)
Water intake (mL/d)	715.2	-	1175.3	1398.4	Abioja <i>et al.</i> (2010)
Feed intake (g DM/day)	402.8	-	445.8	446.0	Abioja <i>et al.</i> (2010)
Growth performance					
Ave. daily gain (g/day)	-108.3	-	16.7	27.4	Abioja <i>et al.</i> (2010)
Nutritional status					
BCS (1-5 scale)	-	-	-	1.6	Rumosa Gwaze <i>et al.</i> (2010)
Body weight (kg)	-	48.3	49.0	49.3	Casamassima <i>et al.</i> (2008)
Glucose (mmol/l)	-	3.1	3.1	3.1	Casamassima <i>et al.</i> (2008)
Creatine (μ mol/l)	-	102.5	94.6	97.2	Casamassima <i>et al.</i> (2008)
Urea (mmol/l)	-	9.7	9.4	8.5	Casamassima <i>et al.</i> (2008)
Cholesterol (mmol/l)	-	2.00	1.8	1.7	Casamassima <i>et al.</i> (2008)

Water Salinity

One of the principal factors affecting water quality and increasing water salinity is the amount of total dissolved salts in water. Under drought-stricken areas, available water resources are saline, reducing the quality of drinking water for goats. The presence of dissolved salts in drinking water for animals' drinking water. These include calcium, magnesium, sodium, chlorine, sulfates, and hydrocarbons that cause harmful effects resulting in poor performance and illnesses that lead to death (Yape Kii and Dryden, 2005; Maldonado-Valderrama *et al.*, 2011). This greatly affects the amount of water that goats can consume (Prasetiyono *et al.*, 2000; Muna and Ammar, 2001). In conditions where water resources are saline, goats tend to reduce water intake when water salinity levels are beyond 8.15 g/L Saline water results in a high loss of body water when animals excrete sodium through urine (Yape Kii and Dryden, 2005). An increase in water salinity caused a decline in feed intake. This is because; water intake is directly related to feed intake (McGregor, 2004b), thereby affecting growth. Various goat breeds common amongst farmers of the southern African region still need further understanding, as this may expand the scope of water stress for indigenous goats. Chimonyo (2016) reported that the adaptability of the Nguni goat to saline water is understood since goats resisted salt toxicity considering that growth was maximized at the highest levels of water salinity tested in the current experiment.

Relationship Between Feed and Water Intake, and Body Weight

Water intake is directly related to feed intake (McGregor, 2004b). Restriction of water intake has often been shown to reduce food intake in humans (Engell, 1988) and various animal species including ruminants (Little *et al.*, 1976). Most animals reduce their feed intake during water restriction and may not eat at all during severe dehydration a marked reduction in the ratio of water intake to dry matter intake during water restriction was shown to reduce water losses in urine and feces associated with a slight increase in the efficiency of digestion (Ikthaua *et al.*, 1985). As feed intake decreases or increases, there is a concomitant change in fecal urinary and evaporative water losses and accordingly in water requirement (Abdelatif and Ahmed, 1992; Sirohi *et al.*, 1997). Dry matter intake, this finding was reported by other workers for sheep (Howard, 1972) and steers (Ikthaua *et al.*, 1985) also similar results were obtained in desert goats when water was restricted to 40% (Ahmed and Elshafei, 2004).

Ferreira *et al.* (2002) measured the water intake of castrated Boer goat kids and Merino lambs indoors they found that goats had a lower water intake per kg of feed intake (1.8 vs 2.61) and per kg of live weight gain (16.4 vs. 24.41) for goats and sheep respectively. Alamer (2009) demonstrated that DMI was reduced in goats subjected to 25% and 50% water restrictions compared with goats with free access to water consumption. Water deprivation affects feed

intake, metabolism, and productivity (Steiger *et al.*, 2001) it also increases RT and RR and arises in urea in blood and milk in sheep (Sevi *et al.*, 2009). Maloiy *et al.* (2008) reported that water restriction at an ambient temperature of 22 °C, a significant and progressively increasing reduction in feed intake from fat-tailed sheep (−48%), to Zebu (−50%) and Turkana goats (−58.3%). The decrease in feed intake under water restriction is also linked to the type of feed that animals receive; in fact, in goats fed legume hay a feed intake reduction of only 18.8% was observed, while this percentage rose to 21.2% when animals were fed meadow hay, which has lower protein content (Muna and Ammar 2001). When water was restricted to 100% the animals reduced their food intake by about 50% for the 3 first days (Soad, 2015).

Water stress is also interconnected with body weight. The weight loss may be due to body water loss and consequent mobilization of fat (and possibly muscle) used for energy metabolism to compensate for the decrease in dietary intake (Jaber *et al.*, 2004). The body weight loss and average daily weight loss of Malpura ewes were higher in water-restricted and it increased with the increase of water restriction levels (Kumar *et al.*, 2016). The body weight (Kg) and dry matter intake (g/d) of sheep and goats were reduced significantly by 5.11 and 11.92% when 50% water restriction in the hot humid seasons than in the hot dry season, respectively (Khanvilkar, 2014). On the other hand, (Casamassima *et al.*, 2008) found no significant effect of water restriction on feed intake, when Comisana sheep were subjected to water restriction (60% and 80% of ad libitum intake) and also (Hassouna; 2012) said that water restriction failed to induce a significant effect on dry matter intake, fecal dry matter output urine volume. Ahmed and Elshafei (2004) found that DMI was not affected by water restriction in desert goats fed high- and low-quality roughages, generally desert sheep and goats are well adapted to water shortage and can easily withstand a watering interval of 3-6 days (Wilson *et al.*, 1962).

Defense Mechanism against Water Stress of Small Ruminants

Many mechanisms work against water stress on small ruminants including behavioral, morphological, physiological, and biochemical mechanisms.

Behavioral Adaptations

Drinking behavior in sheep and goats revealed interesting differences in the behavioral strategies between both species. Drinking behavior was defined as follows: drinking frequency (number of drinking bouts) and drinking duration (time in minutes when the animal was actively engaged in the ingestion and swallowing of water). Under normal conditions, animals in both species spent approximately 0.2% of the 24 h days drinking (2.6 ± 0.7 and 2.7 ± 0.7 min/day for sheep and goats, respectively). Underwater restriction, goats were able to increase their WI per drinking bout to about 0.9 6 0.5 l/bout compared with 0.5 6 0.4 l/bout in sheep, whereas the amount of WI per minute drinking was identical in both goats and sheep. The higher frequency of drinking events in sheep may be related to their evaporative cooling mechanisms because sheep panted more frequently than goats. It is suggested that sheep require more water to regulate their body temperature due to their longer fleece, which increases their endogenous heat production (Al-Ramamneh *et al.*, 2010, 2012)

Feeding behavior is affected by environmental constraints. Nocturnal feeding has been documented in bighorn sheep (Miller *et al.*, 1984) to avoid high temperatures during the day. Similar behavior is also reported in goats (Morand-Fehr, 2005). The author also indicated that feeding frequency is modified in some adapted goats which resort to more frequent and shorter meals to reduce heat production associated with rumen fermentation. Langhans *et al.* (1991) further observed that feed intake is less affected by water deprivation in adapted breeds such as pygmy goats as compared to non-adapted breeds. Furthermore, Lechner-doll *et al.* (1995) observed that adapted goats can select high-quality feed during the dry season while sheep showed less selectivity to high-quality feed.

Morphological Adaptations

Ruminants are usually classified as grazers, browsers, or intermediate feeders. Sheep are usually classified as grazers feeding mainly on grasses while goats are intermediate feeders which can use grasses as well as shrubs (Hofmann, 1989). Morphological characteristics such as body shape and size help reduce heat loads and minimize water losses; it is noted that goat breeds of arid and semi-arid regions are relatively smaller than exotic breeds. Smaller animals benefit from a relatively larger surface area which allows them to better dissipate heat to the environment. Fleece is another feature that plays a major role in controlling body temperature, serving as a thermal barrier that reduces the

effects of ambient temperatures through the formation of a milder microclimate within the fleece (Eyal, 1963). Therefore, thermostability could be maintained without directly resorting to evaporative cooling (panting) which leads to high water loss (Degen and Shkolnik, 1978). The woolly hair coat of sheep in contrast to the skin morphology of goats may play an important role in the better adaptability of the latter to water scarcity (Al-Ramamneh *et al.*, 2012).

Physiological Adaptation

Changes in rectal temperature (OF), pulse rate (no./min.), and respiration rate (no./min.) indicated the adaptability of the animals to increased thirst periods. Dehydration due to the thirst period provoked physiological mechanisms in the body in a manner that helped the animals to survive (Saini *et al.*, 2013). However, for pulse rate, the results were not so conspicuous as for the other physiological parameters. In sheep and goats' physiological responses like rectal temperature, pulse rate, and respiration rate increased significantly when receiving 50% water requirements. Similarly, animals exhibited lower physiological responses in hot humid as compared to the hot dry season.

Rectal Temperature

The rectal temperature of small ruminants was affected by water restriction. Patel *et al.*, (2004) studied the performance of Barbari goats under different management systems, and higher rectal temperature was observed in the morning in summer as compared to in the winter in both grazing and stall-feeding groups. Ghanem *et al.*, (2008) studied the rectal temperature of dry Awassi ewes. In their studies, they observed that rectal temperature increased significantly on water restriction but the rise is comparatively lower in vitamin supplemented water restriction group than non-vitamin supplemented water restriction group. This shows that vitamins help to alleviate the effect of water restriction. Similar results were obtained for respiration rates. Burgos *et al.* (2009) reported that water restriction causes an increase in RT and consequently, Alamer and Al-Hozab (2004) described a significant increase in rectal temperature under conditions of water restriction during the spring and summer seasons in Awassi and Najdi rams; other authors (Ghanem *et al.* 2008) made the same findings in Awassi sheep, which are due to the adaptive response of animals to the breeding environment that serves to reduce water loss through mechanisms of thermoregulation for the defense from heat. Khanvilkar (2014) reported that the rectal temperature of both goats and sheep was increased due to water restriction in hot dry than in the hot humid season. However, the rectal temperature of Goats was lower as compared to Sheep. This implies that rectal temperature is influenced by treatment, species, season, and period of experiment independently as well as in combination with the animals. The RT and RR Nubian goats were increased by water restriction by 50% restriction (Soad, 2015). The decreased PR in the water-stressed group might be due to a decrease in the metabolic rate as a result of reduced feed intake in these groups of animals (Kumar *et al.*, (2016).

Respiration Rate

Breathing is drawing air into the lungs (inspiration) and expelling it from the lungs (expiration), the respiration rate is the number of times per minute that air is inhaled and exhaled when the animal breathes air flow in the lungs which be freely in the thoracic (chest) if the rib and chest increase size the lung expands due to air pressure within them and the inspiration of air through the nostril or mouth. The physiological effect exam, exposure to high a morphemic temperature just after exercise and ingestion feed. Pathological, Fever, Anemia, severe cardiac disease, various diseases, a condition making respiration. Each respiratory cycle has three phases, inspiration, expiration, and pause. The reduction of respiratory acts under water restriction is one of many defense mechanisms which the animal employs to prevent the loss of water and dehydration through pulmonary evaporation. Water deprivation reduced respiration rate during winter and spring and increased rectal temperature during spring and summer. The sweating rate was reduced in water-deprived sheep during summer and the Awassi breed maintained lower sweating activity (Alamer and Al-hozab, 2004).

Al-Ramamneh *et al.* (2012), in experiments carried out on water-restricted Boer goats and black-head sheep in an arid environment, reported a significant decrease in the respiratory rate only for sheep. Rahardja *et al.* (2011), in their experiments evaluating water restriction by 50% in fat-tailed sheep and Kacang goats in a hot and dry area, observed a significant increase in respiratory rate to prevent an increase in body temperature only in sheep. Khanvilkar (2014) reported that the respiration rate recorded at 7.30 a.m. and 2.30 p.m. significantly increased by 13.66 and 13.81% in Sheep, respectively, when exposed to water restriction whereas, the corresponding values in

Goats were 22.66 and 5.19%, respectively. However, respiration rate decreased significantly in the hot humid season at 7.30 a.m. only increased to the tune of 8.45 and 10.51% in Sheep and Goats, respectively. The Goats exhibited a significantly higher (11.85%) respiratory rate than the Sheep. Also, (Hassouna, 2012) said that water restriction increased RT and RR when used Nubian goats and desert sheep as being affected by 50% water restriction. The decrease of RR might be due to less available energy in water-restricted ewes as DM intake is also reduced after water restriction.

Pulsation Rate

Pulse rate helps in the diagnosis of a circulatory disturbance, use arteries because arteries are superficially situated of medium size lying in adherence with solid mass as bone (femoral artery), Rate is the number of blood waves (beats) felt in a minute time. Physiological factors affecting the pulse rate in normal Animals, species, size, age, sex, parturition, and late pregnancy relative more pulse rate, Exercise, Ingestion feed, and Posture (Natural Resource Design, 2010). Pulse rate is also affected by water stress. The pulse rate of Sheep recorded at 2.30 p.m. has been observed (6.4%) significantly higher in the 50% water restriction group as compared to the control, with the corresponding values for Goats (1.67%). Similarly, Sheep in the hot humid season exhibited a significantly higher (9.38%) pulse rate at 2.30 p.m. in hot humid as compared to the hot dry season. The corresponding values for Goats were (11.52%) which again indicated that the pulse rate did not increase much as for Sheep (Khanvilkar (2014).

Water restriction caused a rise in rectal temperature but did not affect either respiration or pulse when Awassi sheep were subjected to 50% water restriction for 4 days (Ghanem *et al.*, 2008). The respiration rate and sweating rate were not affected by water restriction and therefore, rectal temperature was maintained without changes compared to 25% and 50% water restriction. This indicated that lactating Aardi goats can tolerate 50% water restriction with minimal physiological alterations even when it was coupled with a high ambient temperature (Alamer, 2010). Similarly, the rectal temperature, heart rate, and respiration rate of the Tswana goat were not affected by the 50% water restriction (Qinisa, 2010).

Blood Chemistry

Blood Serum Metabolites

The biochemical parameters of small ruminants are affected by water restriction. Water restriction significantly changed the serum concentration of total protein, urea, creatinine, sodium, chlorine, ROMs, and cortisol (Casamassima *et al.*, 2016). An increase in the concentration of serum proteins was observed by Mengistu (2007) in Ethiopian-Somali goat water-restricted for four days, and by Jaber *et al.* (2004) in Awassi ewes subjected to two different regimens of water restriction. Water restriction caused an increase in serum total protein and globulin by 13% and 14.12% respectively compared with ad libitum water intake (El Khashab *et al.*, 2018). The observed significant increase in serum total proteins might be due to a reduction in plasma volume caused by dehydration (Khalil *et al.*, 1990). The increase in serum total proteins might cause an increase in plasma colloid osmotic pressure (Cole, 2000). Water restriction caused a decrease in serum glucose concentration by 10.90% compared with the control group (El Khashab *et al.*, 2018). And also, Kumar *et al.*, (2016) found that the glucose and cholesterol levels were lower ($P < 0.05$) at 20% less than ad libitum water intake compared with the control ad libitum water. Some reports stated that glucose metabolism decreases because of decreased propionate production in the rumen as feed intake reduces following water restriction.

Serum Mineral Profile

The serum mineral profile of the goat is increased with water stress. The serum concentrations of sodium, chlorine, and potassium level in water restricted to does were increased (El Khashab *et al.*, 2018). This increase might be due to sweating rate and excretory pattern. Also, the ability of the goat's kidney to concentrate urine and conserve water caused variations in blood volume, as proposed by Ashmawy and Ibrahim (1999). In addition, this increase in Na⁺ and Cl⁻ in restricted goats may be accompanied by an increase in blood osmolality and osmosis balance as a result of dehydration as previously noticed in 72 h water deprivation, which is preceded by losses from the intracellular pool and a decrease in extracellular water volume (Cole, 2000). The increase in Na⁺ when sheep were deprived of water might be due to adrenal response to this stress in an attempt to maintain plasma volume or probably due to a decrease in extracellular fluid volume (More and Sahni, 1980). The slight decrease in serum K⁺ in goats

might be due to K^+ elimination in the urine.

The restriction resulted in a progressive increase in serum sodium and chlorine in sheep. The increase in serum chloride and sodium concentrations is due to the reduction in plasma volume and increased serum levels of aldosterone and vasopressin. This promotes increased sodium retention and water adsorption at the kidney level, leading to a hemodilution in an attempt to restore the physiological values of sodium and chlorine (Casamassima *et al.*, 2016). Other authors (Rawda 2003; Hanna 2006; Ghanem *et al.* 2008) reported a strong influence of water intake on sodium ion concentrations in sheep plasma; the reduction of plasma volume in response to water restriction causes an increase in blood plasma osmolality and leads to the concentration of electrolytes in plasma (Qinisa *et al.* 2011), in particular, an increase in sodium and chloride ions as has been reported by different authors for sheep and goats (Alamer 2005; Jacob *et al.* 2006; Karnib 2009).

Hematological Parameters

Casamassima *et al.*, (2016) reported that the increase in the values of some blood count variables (RBC, HGB, HCT, and MCHC) of Lacaune ewes could be attributed to water restriction, which produced a reduction in plasma volume and their haematic concentration. This has also been reported by Hamadeh *et al.* (2006) in Awassi sheep. In particular, the progressive increase in RBC, in response to water restriction, leads to secondary polycythemia due to a gradual reduction in circulating blood volume and not due to an increase in red blood cells. When this condition persists over time, it leads to a slowing of blood flow in animals, which in turn causes several pathological events.

Water restriction caused a decrease in hematocrit (HT) (El Khashab *et al.*, 2018). This decrease in hematocrit values during water restriction is partially due to a decrease in circulating erythrocytes (Nejad *et al.*, 2014), MCV, and platelets by 11, 6.53, and 11.26% respectively compared to the control group. While an increase of 15.7% in MCHC of the treated goat was noticed compared with ad libitum water intake may be due to a decrease in Ht value. Water restriction has barely affected the Hb, MCH, and RBC count in goats (El Khashab *et al.*, 2018). Nejad *et al.* (2014) found that the values of RBCs remained unchanged through a water restriction regime. Moreover, insignificant differences were noticed in WBCs count and its differential of the water restriction group compared to the control group (El Khashab *et al.*, 2018), which is parallel to Nejad *et al.*, (2014) who reported concentrations of white blood cells were not a significant difference.

Hematology: PCV and Hemoglobin

Packed cell volume (PCV), the proportion of erythrocytes expressed as a percentage of the volume of whole blood per given sample (Kusiluka and Kambarage, 1996), is the most precise means of determining red blood cell volume and can be used to deduce total blood volume and hemoglobin levels. Analysis of normal goat hematocrit values is essential for the diagnosis of various pathological and metabolic disorders (Grunwaldt *et al.*, 2005). Cell volume values higher than the reference values could indicate dehydration due to diarrhea, erythroze, and polycythemia vera. Packed cell volume is influenced by the sex of the goat and altitude (Tibbo *et al.*, 2004), management, age (Grunwaldt *et al.*, 2005), sex, breed, health status, ambient temperature, and physiological status (Kaneko, 1997). Dehydration in warm weather conditions reduces plasma volume as water is taken up by the tissue (Schaefer, 1990), and also that increased PCV and Hb and concentration are good indicators of dehydration (Ghanem, 2005). Results on these two parameters have been inconclusive.

Even though levels of hematocrit were found to increase in Awassi (Ghanem, 2008) and Merinos (Ghanem, 2005) subjected to water stress in some experiments, no variation was remarked in Awassi (Jaber *et al.*, 2004) and sheep (Li *et al.*, 2000) under similar watering conditions. An elevation in hemoglobin level was attributed to a decrease in plasma volume due to water loss (Li *et al.*, 2000). These undetermined results may be an indication that adapted sheep can maintain plasma volume and redistribute body water after a long water deprivation period (Ashour and Benlemlih, 2000). Khanvilkar (2014) reported that Hb (g %), PCV (%), and blood glucose (mg/dl) levels of sheep and goats were significantly decreased, increased, and at par, respectively, when animals received 50% less water than the requirement. Hb (g %), PCV (%) and RBC ($X10^6/\mu l$) counts were significantly lower in Goats as compared to Sheep. The Hemoglobin (Hb) and packed cell volume (PCV) of Malpura ewes in a semiarid were higher with water restriction. The reason for increased Hb and PCV could be severe haemoconcentration as a result of less drinking water availability (Kumar *et al.*, 2016).

Adaptation of Small Ruminants to Saline Water

The relationship between physiological parameters and salinity levels in drinking water for goats is different between and/or with species and breeds of animals. Physiological mechanisms developed by goats to tolerate drinking water with elevated salt content levels include the kidney's ability to concentrate urine and the kidney's ability to reduce urinary water loss during dehydration; feeding during cooler times of the day; increased urinary output; increased water intake and decrease in feed intake; increased rate of respiration (Gihad *et al.*, 1993). In sheep, salinity decreased blood volume, plasma volume, and interstitial fluids which play an important role in coping with heat stress by evaporation (Assad and Elsherif, 2002). The respiration rate increased in goats drinking saline well water (0.8 %), while rectal temperatures and pulse rate were only slightly affected by El Gawad (1997). The rectal temperature was lower while the heifers consumed 2% salt drinking water and were unaffected by the 1% NaCl Weeth *et al.* (1960). The respiration rate for goats that consumed 5.5 and 11 g of TDS / L of water generally decreased over time. Salinity affected pulse rate. The pulse rate of goats that consumed 5.5 and 11 g of TDS / L generally decreased over time (Mdletshe *et al.*, 2017). The observed increase in PR at 11 g TDS/L, when compared to the control, agrees with earlier reports (Kii and Dryden, 2005). Higher PR indicates that goats in 11 g TDS/L saline treatment levels were less tolerant when compared to the control and 5.5 g TDS/L saline treatment level. Nguni goats have a physiological mechanism to excrete excessive salt in the body. Higher PR also indicates that goats were directing more energy to the heart to excrete excess salt from the body system.

Blood volume, plasma volume, extracellular fluids, and interstitial fluids decreased by increasing salinity concentration for ewes and also, and plasma glucose level decreased by salinity (13,535 ppm TDS), while camels were not affected (Assad *et al.*, 2002). In sheep, both plasma sodium and urea concentrations decreased significantly by drinking 0.45% NaCl, although no further change was recorded with the increase in salt loading to 0.9% NaCl, while plasma potassium concentration increased by drinking 0.45% NaCl, and increased even further with 0.9% NaCl in the drinking water (Meintjes and Engelbrecht, 2004). Albumin, triglycerides, total protein concentrations, and Gamma-GT activity in plasma are indicators of liver function and animal nutritional status (Barnouin *et al.*, 1981; Braun, 1983). Plasma concentrations of glucose, urea, and gamma-glutamyltransferase (Gamma-GT) were highest with salinity levels in rams. Plasma glucose concentration in sheep was not affected by the addition of 11 g of NaCl / L to drinking water, but increased by 25% with the administration of the highest salt level in the water and also the decrease in insulin level induced by the decrease in feed intake in sheep drinking saline water (Yousfi and Salem, 2017).

Plasma creatinine and urea are indicators of kidney function and the kidney and liver have antagonist functions. But, if uremia exceeds 50 cg/l, then both the kidney and liver participate in the induction of high uremia (Labouche, 1970). Plasma creatinine and urea were higher in sheep that had access to saline water than in control sheep. The increase of urea and creatinine in sheep drinking saline water would suggest an alteration in kidney function (Yousfi and Salem, 2017). The adaptive mechanism responsible for tolerance to drinking water with excessive salt levels in goats includes the reduction of moisture in the stool, the increase in urine volume associated with high water intake; and the increase in sodium-potassium adenosine triphosphatase (NAK ATPase) in the ileum, liver, and kidneys (McGregor, 2004).

Conclusion

Generally, water is the simplest of all substances present in food; however, managing it is not as simple. Goats and sheep, throughout their generations, were subjected to adaptive processes that increased the efficiency of water use. Most small ruminants respond to water stress by decreasing their food intake, resulting in a reduction in weight due to water and body mass loss. The rumen plays an important role as a water reservoir both in times of dehydration, to maintain blood volume, and upon rehydration to prevent hemolysis. Similarly, modulating saliva production and osmolality is an important mechanism for facing dehydration and rehydration cycles. Biochemical parameters like blood serum hormones, mineral profile, metabolites, and liver-kidney function were not affected by water restriction in goats so goats may survive at 50% restriction of water without affecting physiological indices and then their production. Furthermore, the decrease in body weight gain and the variation in physiological response and blood parameters in water-restricted animals reflect different adaptive strategies to counteract water restriction, as water restriction can increase stress in animals.

Conflict of Interests

There is no conflict of interest.

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