Influence of water stress on feed intake, growth performance and nutritional status of Nguni goats

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DECLARATION

Regardless of the acknowledgements provided as citations or quotes right across this document, this Thesis is the author's own original work under the supervision of Professor Michael Chimonyo at the University of KwaZulu-Natal (Pietermaritzburg campus). This thesis has and will not be submitted to any other institution.

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ABSTRACT

Influence of water stress on intake, growth performance and nutritional status of Nguni goats

By

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The broad objective of the study was to determine the influence of water stress (water deprivation, water restriction and water salinity) on feed intake, growth performance and the nutritional status of Nguni does. A cross-sectional survey was conducted to 135 farmers that keep goats from Jozini municipality of uMkhanyakude district in South Africa. Data collected included household demographics, goat production constraints, watering and feeding systems practised, including data regarding whether farmers milk goats. Varying periods of water deprivation (0, 24 and 48 h) on water intake, feed intake, water to feed ratio, average daily gain and feed conversion ratio were determined. Varying levels of water restriction (1000, 1200, 1400, 1600, 1800 and 2000 mL) and water salinity (0, 5.5 and 11 g/L) on average daily feed intake (ADFI), water to feed ratio (WFR), average daily gain (ADG) and feed conversion ratio (FCR) of Nguni goats were determined. Varying periods of water deprivation (0, 24 and 48 h) on body condition scoring (BCS), body weight (BW), faecal egg counts (FEC), FAMACHA scores, glucose, creatine, urea and cholesterol of Nguni goats were also determined. Varying levels of water restriction (1000, 1200, 1400, 1600, 1800 and 2000 mL) and water salinity (0, 5.5 and 11 g/L) on body condition scoring, body weight, faecal egg counts, FAMACHA, glucose, creatine, urea and cholesterol of Nguni goats were determined.

Farmers were not aware of the value of goat milk, and they largely value meat from goats (P <0.01). Female farmers were likely to face water challenges (P <0.05). Farmers practising the scavenging production systems were likely to experience feed challenges. The ADWI was the same in goats deprived of water for 0 h and 24 h (P <0.05). The ADFI was largest for goats deprived of water for 48 h (P <0.01). The ADG and FCR declined as the level of water deprivation was increased (P <0.01). Water deprivation period was negatively correlated with ADFI, WFR, ADG and FCR. The ADFI peaked at 1600 mL of water restriction for goats subjected to 0 and 5.5 g/L of water salinity (P <0.01). The ADG peaked at 1400 and 1600 mL of water restriction across all water salinity levels (P <0.05). Body condition scoring and body weight were largest for goats deprived of water for 0 h (P <0.01). The FEC increased as water deprivation period was increased. Correlations between water deprivation period with FAMACHA, BCS and BW were negative. Correlations with FEC and creatine kinase were, however, positive. The BCS and FAMACHA scores to the peak, and later declined beyond 80 % of water restriction for goats subjected to 0 and 5.5 g/L of water salinity (P <0.05). The BW increased as the level of water restriction decreased across all water salinity levels tested (P <0.01). The FEC decreased as the level of water restriction decreased for goats subjected to 0 and 5.5 level of water salinity (P <0.05). Creatine concentration decreased as the level of water restriction was decreased across all water salinity levels tested (P <0.05). There was a linear relationship between urea and water restriction for goats subjected to 0 g/L of water salinity (P <0.05). It was concluded that goats are constrained by lack of input resources such as water. On

the other hand, water deprivation period can be set to 24 hours for Nguni goats since increased periods of water deprivation compromise goat productivity. Also, water restriction and water salinity for Nguni goats can be set to 1600 mL and 5.5 g/L, respectively since further increments do not seem to improve goat productivity.

Key words: water resources, water stress, productivity, Nguni goats

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CHAPTER 1: General Introduction

1.1 Background

World goat numbers are estimated at 861.9 million, where 34 % are found in Africa (Aziz, 2010). The majority of goats are found in arid and sub-tropical regions, where water availability and quality is a challenge (El Khidir *et al*., 1998; Zamiri *et al*., 2012). In South Africa, goat numbers have increased over the years, from 4.8 million in 2002 to about 6.5 million goats in 2009 (Botha and Roux, 2008; King, 2009; 602Rumosa Gwaze, 2009). Goats can be used to contribute to food security (Chimonyo *et al*., 2005; Rumosa Gwaze *et al*., 2009). Goats are considered as the "poor man's cows" for farmers that cannot afford to own cattle. Goats display numerous advantages such as small forage requirements including their ability to adapt to water-saving mechanisms (Lehloenya *et al*., 2005; Silanikove, 2000; Alamer, 2006). These are good adaptive characteristics considering the continued over-grazing resulting in limited availability of water and forage resources in drought-stricken areas. Goats adapt to water shortages through limiting dry matter intake. Water and feed resources have a direct relationship (Silanikove, 2000). Goats also save water by limiting respiration, and storing water in their extracellular spaces when water is abundant to ensure availability of sufficient water for metabolism during water deficit. This is important to consider since it is widely known that sub-Saharan regions are facing water crisis (Mabhaudhi *et al*., 2013; News24, 2014).

Water scarcity in sub-Saharan Africa is topical. Water a scarce resource that threatens the future of the livestock industry. Water challenges are expected to more than double in the next decade, resulting in more competition for water resources between humans and agricultural activities

(Wallace, 2000). Such water demands from livestock operations are resultant of the ever-increasing demand for livestock products, resulting in increased commercialization of the livestock industry (Descheemaeker *et al*., 2010). Livestock operations that ensure minimum use of water resources can help ensure farmer livelihoods, at the same time benefiting the environment (Bossio, 2009), with more attention being paid to livestock. One way to do that is through the identification of livestock species that are water economic such as goats for use towards minimizing water challenges. This includes the application of water-saving practices in agriculture to prepare for future water resource unavailability for livestock (Wallace, 2000; Descheemaeker *et al*., 2010).

Goats travel long distances to access water points, far away from grazing areas such that they can go for days without drinking water. Where water points are available, water resources are not enough to meet daily requirements of goats. At the same time, the available water points may consist of saline water. Both the availability and salinity of water influence goat productivity. Studies pertaining water deprivation, water restriction and water salinity on goat productivity have been done using various other goat breeds of desert origin such as the Awassi and the Red Sokoto goat breeds (Alamer, 2009; Attia-Ismail *et al*., 2008; Abioja *et al*., 2010).

To understand adaptation of goats to water stress, it is important to consider farmer perceptions about water utilisation for goats. This helps to understand challenges that farmers face so that strategies that directly address the circumstances that farmers are exposed to can be devised. On the other hand, the influence of water shortages on Nguni goat productivity is largely unclear. Therefore, it is necessary to monitor water and feed intake, including growth performance and the nutritional status of indigenous goats to water deprivation, water restriction and consumption of saline water. As much as goats adapt to water shortages, the extent of adaptability of Nguni goats found in southern African regions is poorly understood (Kay *et al*., 1997).

1.2 Justification

Considering that the livestock industry is the fastest growing sector in agriculture globally, there is need to devise strategies that assist farmers sustain productivity in the near future since water shortages keep intensifying with time (Descheemaeker *et al*., 2010). Management strategies pertaining water scarcity for goats need to consider water deprivation where water resources are far from grazing areas for goats, including water restriction and water salinity where water resources insufficient. Findings from the current study benefits farmers ensuring through understanding of the ability of Nguni goats to withstand water stress. Water deprivation, water restriction and water salinity all affect goat productivity (water and feed intake, growth performance and the nutritional status). The use and promotion of Nguni goats, which are predominant among resource-limited farmers enhances sustainability of smallholder farming systems (Mpendulo *et al*., 2016). Minimising water use by Nguni goats has the potential to counteract the global crisis of water scarcity and minimizing the competition for water as a resource between humans and livestock (Arnell, 1999). Therefore, improving goat productivity through efficient utilization of water as a resource in livestock production systems can benefit both the environment and people's livelihoods.

1.3 Objectives

The broad objective of the current study was to determine the influence of water stress (water deprivation, water restriction and water salinity) on intake, growth performance and the nutritional status of Nguni does. The specific objectives were to:

1. Identify opportunities for improving the contribution of Nguni goats to rural livelihoods for resource-poor farmers in semi-arid environments;
2. Assess the influence of water deprivation on intake and growth performance of Nguni does;
3. Determine the influence of water restriction and water salinity on water intake and growth performance Nguni goats;
4. Assess the influence of water deprivation on the nutritional status of Nguni does; and
5. Determine the influence of water restriction and water salinity on the nutritional status of Nguni does.

1.4 Hypotheses

The hypotheses tested were that:

1. Nguni goats contribute significantly to livelihoods of resource-poor farmers;
2. Water deprivation influence intake and growth performance of Nguni does;
3. Water restriction and water salinity influence intake and growth performance of Nguni does;
4. Water deprivation influence nutritional status of Nguni does; and
5. Water restriction and water salinity influence the nutritional status of Nguni does.

1.5. References

Abioja, M.O., Osinowo, O.A., Adebambo, O.A., Bello, N.J. and Abiona, J.A., 2010. Water restriction in goats during hot-dry season in the humid tropic: feed intake and weight gain, Annales de Zootechnie, 59, 195–203.

Alamer, M., 2006. Physiological responses of Saudi Arabia indigenous goats to water deprivation, Small Ruminant Research, 63: 100–109.

Alamer, M., 2009. Effect of water restriction on lactation performance of Aardi goats under heat stress conditions, Small Ruminant Research, 84: 76–81.

Arnell, N.W., 1999. Climate change and global water resources. Global Environmental Change 9: S31–S49.

Attia-Ismail, S.A., Abdo A.R. and Asker, A.R.T., 2008. Effect of salinity level in drinking water on feed intake, nutrient utilization, water intake and turnover and rumen function in sheep and goats, Egyptian Journal of Sheep and Goat Sciences, 3(1): 77–92.

Aziz, M.A., 2010. Present status of the goat populations and their productivity. Lohmann Information, 45(2): 42.

Bossio, D., 2009 Livestock and water: understanding the context based on the 'Compressive Assessment of Water Management in Agriculture'. The Rangeland Journal. Volume 31, Article 2: 179-186

Botha, A. F. and Roux, J. A., 2008. Fibre, yarn and fabric properties of South African indigenous goat hair. 4th International Cashmere/wool Technique Symposium. Erdos City, China, 17-18 November, pages 140-147.

Chimonyo, M., Bhebhe, E., Dzama, K., Halimani, T.E. and Kanengoni, A., 2005. Improving smallholder pig production for food security and livelihood of the poor in Southern Africa, African Crop Science Conference Proceedings, 7: 569-573.

Descheemaeker, K., Amede, T. and Haileslassie, A., 2010. Improving water productivity in mixed crop-livestock farming systems of sub-Saharan Africa. Agricultural Water Management, 97: 579-586.

El Khidir, I.A., Babiker, S.A. and Shafie, S.A., 1998. Comparative feedlot performance and carcass characteristics of Sudanese desert sheep and goats, Small Ruminant Research, 30: 147-151.

Kay, R. N. B., 1997. Responses of African livestock and wild herbivores to drought, Journal of Arid Environments, 37: 683–694.

King, F. J. M., 2009. Production parameters for Boer goats in South Africa, Dissertation (MSc), University of the Free State, Bloemfontein, Republic of South Africa.

Lehloenya, K. C., Greyling, J. P. C. and Schwalbach, L. M. J., 2005. Reproductive performance of South African indigenous goats following oestrous synchronization and AI, Small Ruminant Research, 57: 115–120.

Mabhaudhi, T., Modi, A.T. and Beletse, Y.G., 2013. Growth, phenological and yield responses of a Bambara groundnut (*Vigna subterranea* L. Verdc) landrace to imposed water stress: II. Rain shelter conditions Water South Africa, 39: 191–198.

Mpendulo, C.T., Chimonyo, M. and Zindove, T.J., 2016. Influence of water restriction and water salinity on feed intake and growth performance of Nguni does, Small Ruminant Research, Accepted: Manuscript number: Rumin-D-15-7343.

News24, 2014. SA a water-scarce country - Zuma. [Online] Available from: http://www.news24.com/SouthAfrica/News/SA-a-water-scarce-country-Zuma-20141101. [Accessed: 10th November 2015].

Rumosa Gwaze, F., Chimonyo, M. and Dzama, K., 2009. Communal goat production in Southern Africa: a review, Tropical Animal Health and Production, 41: 1157–1168.

Rumosa-Gwaze, F., 2009. Communal Production Systems of Goats Raised by Resource-Poor Farmers in the Eastern Cape Province of South Africa, Dissertation (PhD), University of Fort Hare, Alice, Republic of South Africa.

Silanikove, N., 2000. The physiological basis of adaptation in goats to harsh environments: a review, Small Ruminant Research, 35: 181-193.

Silanikove, N., Leitner, G., Merinc, U., Prosser C.G., 2010. Recent advances in exploiting goat's milk: Quality, safety and production aspects, Small Ruminant Research, 89, 110–124.

Wallace, J., 2000. Increasing agricultural water use efficiency to meet future food production, Agriculture, Ecosystems and Environment, 82: 105–119.

Zamiri, M.J., Eilami, B. and Kianzad, M.R., 2012. Effects of castration and fattening period on growth performance and carcass characteristics in Iranian goats, Small Ruminant Research, 104: 55– 61.

CHAPTER 2: Literature review

2.1 Introduction

Goats survive under harsh conditions characterized by poor water resources (Silanikove, 2000; McGregor, 2004a; Alamer, 2009). They have the ability to minimize water loss through various water-saving mechanisms (Alamer *et al*., 2009). One of the water saving mechanism is that they can store water in the rumen and maintain a large extracellular volume when fully hydrated (Mengistu *et al*., 2007). Such advantages make them ideal where water resources could be limiting, including saline water. The extent of adaptation of Nguni goats to water of varying amounts and quality is not understood. Exploring the response of goats to water stress provides a platform of understanding the extent of adaptation of goats to poor resources. This is because the water scarcity in the southern African region is a growing concern due to the ever-increasing frequencies and intensity of droughts, resulting in increased competition for water between humans and livestock (Mabhaudhi *et al*., 2013; News24, 2014). During a drought, goats have to travel long distances away from grazing areas in search for water point. When water points are available, water is not sufficient to meet the daily requirements for goats, and contain considerable amounts of dissolved salts such as sodium, causing salinity (McGregor, 2004a; Alamer, 2009). The current review discusses goat production systems, performance of indigenous goats under communal production systems and behaviour of goats subjected to water stress.

2.2 Goat production systems found in the southern African region

The southern African region consists of a wide variety of common goat breeds across all production systems. These include the Nguni, Tswana, Mashona, Matebele and the Landim breed (Rumosa Gwaze *et al*., 2009). Goat production systems involve scavenging, back-yard, and semi-intensive, including the intensive production systems, all of which are faced with water scarcity. Under the scavenging production system, goats survive by roaming freely and feed on browse, crop by-products and grasses, where goats hardly receive dietary supplementation (Bouwman *et al*., 2005). Under the back-yard production system, goats feed on various feeding materials such as browse, crop by-products, grasses and rotten vegetables. Input resources supplemented are usually availed by women, since they largely care for small animals (Shackleton *et al*., 2001; Hassan *et al*., 2011).

In general, semi-intensive production system involves the use of selected breeds on smaller pieces of land, including investment on infrastructure, and is market driven (Castel *et al*., 2003; De Rancourt *et al*., 2006). Semi-intensive production system is practised by a group of farmers as development projects to meet market demands for meat and milk. For example, in Honduras, farmers have been encouraged to partake in goat project mergers that involve contract-binding, ensuring maximum commitment of farmers to projects (Ketzis, 1997). Such initiatives involve close monitoring of projects by relevant stakeholders, including a controlled systematic management that farmers are enforced to follow to ensure success of projects. Under intensive production systems, goats are reared using artificial or natural rearing systems, including inclusion of protein and energy sources (Herrera *et al*., 2011). Under this production system, farmers tend to use fast-growing breeds to ensure efficient chevon production.

Goats are found across all production systems, therefore, the adoption of each production system should suit the farmers accordingly, taking into account issues pertaining water scarcity. In that regard, there is need to understand adaptation strategies that farmers need to adopt to help goats withstand water challenges that threaten the future of the goat industry.

2.3 Measures of goat productivity

Goat productivity indices include water and feed intake, growth performance and nutritional status. Goat productivity is influenced by the amount and quality of input resources, which are largely influenced by season (Silanikove, 2000; Tolera *et al*., 2000).

2.3.1 Water and feed intake of indigenous goats

Water to goats serves various purposes such as that being the medium is needed to ensure softening of feed including digestion and fermentation of feed (Adogla-Bessa and Aganga, 2000). A sufficient amount of water ensures maximum feed intake which later encourages fast growth of goats. It has been reported that water intake is positively correlated to feed intake (Prasetiyono *et al*., 2000). Goats consume more feed when water is available in amounts that suit their daily requirements. For example, Muna and Ammar (2001) reported a decrease in feed intake as the water restriction was increased in Sudanese desert goats fed on Lucerne hay and Sorghum hay. Table 2.1 shows feed intakes of common indigenous goats found in the southern African region. However, the response of various indigenous goats to water stress is still not clearly understood. This is necessary since water scarcity is a global challenge that seems to threaten the livestock industry in the near future. Performance of goats

Table 2.1: Intake and growth performance of indigenous goats of the southern African region

Breed	Origin	Water intake (l/day)	Feed intake (kg/day)	Average daily gain (g/day)	Feed conversion ratio (g feed/g gain)	Source
Mashona	Zimbabwe	-	-	60.2	-	(Ndlovu and Simela, 1996)
Matebele	Zimbabwe	3.7	1.3	68	11.4	(Hatendi *et al*., 1992) (Sibanda *et al*., 1997)
Nguni	Swaziland, Lesotho, South Africa	-	1.0	65.3	21	(Bengaly *et al*., 2007)
Boer	South Africa	2.3	1.3	-	9.1	(Erasmus, 2000) (Al-Ramamneh *et al*., 2010)
Tswana	Botswana, Zimbabwe, South Africa	3.2	1.1	85.5	9.3	(Nsoso *et al*., 2003) (Adogla-Bessa and Aganga, 2000)
Malawi	Malawi	1.8	5.9	37	-	(Banda *et al*., 1993) (Ogwang, and Karua, 1994)

subjected to water deprivation have been explored for Tswana goat breeds (Adogla-Bessa and Aganga, 2000). Exploring such stress factors to help understand the nutritional status of common goats found in the southern African region remains unclear. By so doing, the scope pertaining goat productivity can be complete. Goats depend on available water resources that are largely limiting, especially in dry seasons. Understanding water utilisation can help farmers efficiently manage the available resources to ensure maximum productivity from indigenous goats. Goats tend to consume more water not necessarily to satisfy their daily water requirements, but to counteract excessive thirst brought about by excessive drinking (Adogla-Bessa and Aganga, 2000; Prasetiyono *et al*., 2000).

2.3.2 Growth performance of indigenous goats

Growth performance pronounces time taken to reach slaughter weight, thereby, improving access to animal protein and farmer income (Hango *et al*., 2007). Growth performance for indigenous goats is largely low when subjected to insufficient quantity and quality of input resources such as water, including management (Silanikove, 2000; Rumosa Gwaze *et al*., 2009; Moyo *et al*., 2012). High availability and consumption of water encourages feed intake, contributing to growth. Low availability of water impacts negatively on growth performance for goats, especially during dry seasons (Tolera *et al*., 2000; Alamer, 2009; Sebsibe *et al*., 2007). Table 2.1 shows the intake and growth performance of common indigenous goats found in the southern African region. There are huge variations in water intake. Such variations in water intake and feed intake can be linked to differences in the quality of water resources available to farmers (Prasetiyono *et al*., 2000; Muna and Ammar, 2001). These findings suggest that goats subjected to small amounts of water or to water that is of poor quality experience reduced forage intake, limiting the potential of goats to grow. It is necessary to subject goats to water stress so as to monitor the extent with which goats can withstand stress factors such as water deprivation, water restriction and water salinity since drought in southern Africa poses a threat to the livestock industry.

2.3.3 Nutritional status of indigenous goats

Nutritional status of goats is largely influenced by the amount of feed an animal consumes, which is due to the quantity and quality of drinking water for goats (Estrada-Cortes *et al*., 2009). Biological responses such as body condition scoring, body weight and blood metabolites have not been well documented to give an indication of the well-being of goats found in the southern African region (Rumosa Gwaze *et al*., 2010). An overview of the nutritional status of indigenous goats found in the southern African region is given in Table 2.2.

2.3.3.1 Body condition scoring of indigenous goats

Body condition scoring (BCS) is a simple and easy technique, which allows subjective assessment of an animal's body composition and nutrient reserves, to help in adopting appropriate management strategy (Nsoso *et al*., 2003). The technique is easily applicable, and can easily be adopted by farmers to measure the body reserves in livestock. Body condition scoring is ideal for resource-poor farmers because it not labour intensive. Most resource-poor farmers lack capital, and keep livestock under poor management practices (Chimonyo *et al*., 2005; Rumosa Gwaze *et al*., 2009). Several studies have correlated BCS with body weight gain in the assessment of the nutritional status of livestock (Nsoso *et al*., 2003; Rumosa Gwaze *et al*., 2010). Although, Rumosa Gwaze *et al*. (2010) suggested the consideration of blood metabolites

Table 2.2: Nutritional status of indigenous goats of sub-Saharan Africa

Breed	Origin	BCS	BWG (kg)	Blood metabolites				Source
				Urea (mmol/L)	Creatinine (μmol/L)	Glucose (mmol/L)	Cholesterol (mmol/L)	
Nguni	Swaziland, Lesotho, South Africa	1.5-1.6	22.8	7.22-6.17	77.3-69.3	3.0-2.7	2.01-1.99	(Rumosa Gwaze *et al*., 2010) (Bengaly *et al*., 2007)
Boer	South Africa	-	-	2.4	76.83	9.10	0.79	(Kioumarsi *et al*., 2011)
Tswana	Botswana, Zimbabwe, South Africa	1.89-2.74	8.50	7.23	-	-	1.14	(Aganga *et al*., 2000) (Madibela and Segwagwe, 2008)

Abbreviations: BCS: body condition scoring, BWG: body weight gain per week as a measure that should be coupled with body condition scoring and body weight gain when assessing the nutritional status of goats.

2.3.3.2 Body weight of indigenous goats

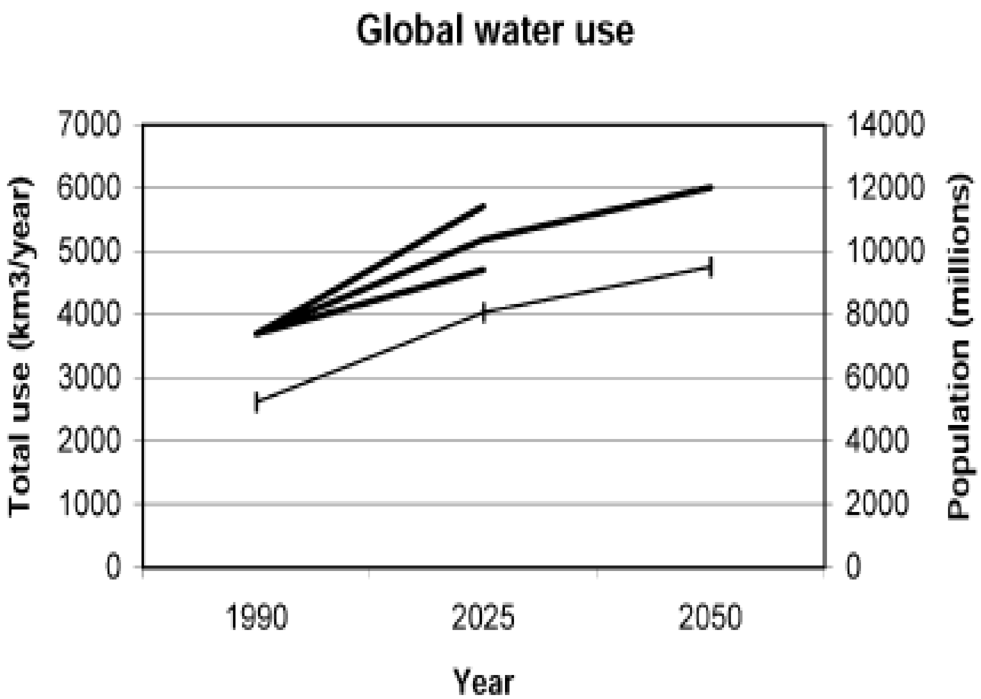
Body weight is the amount of muscle accumulated by an animal up to mature weight. The increase or decrease in body weight is influenced by the degree of availability and the nutritional quality of feed resources available, including the ability of the goat to utilize the available feed resources (Nsoso *et al*., 2003; Shrestha and Fahmy, 2005; Rumosa Gwaze *et al*., 2010). Goats tend do exhibit larger body weight gains in wet seasons compared to dry seasons. This is because; the abundant availability of natural water resources which in turn influence feed utilization since vegetation is highly available in wet seasons for grazing livestock. Since water influence the amount of feed an animal can take, there is need to capture the influence of water stress when examining body weight of goats (Nsoso *et al*., 2003; Shrestha and Fahmy, 2005; Rumosa Gwaze *et al*., 2010). This can help in understanding the appropriate goats that have body weights that correspond to the available resources, particularly during droughts (McGregor, 2004b; Alamer, 2009).

2.3.3.3 Blood metabolites of indigenous goats

Blood metabolites are considered to be the most accurate measure for assessing the nutritional status of goats compared to other measures used such as body condition scoring and body weight gain. They are a direct measure that considers blood parameters giving the utmost possible accuracy (Madziga *et al*., 2013). These include glucose, blood urea, creatinine and cholesterol (Grunwaldt *et al*., 2005; Ndlovu *et al*., 2007). Blood metabolites for goats raised on natural rangelands of southern Africa are shown in Table 2.2. Literature largely reports on the nutritional status of goats based on feed quality and quantity offered to the goats (Pambu-Gollah *et al*., 2000; Rumosa Gwaze *et al*., 2010). Assessment of blood metabolites in relation to the quantity and quality of feed, but ignoring the global challenge on the scarcity of drinking water for goats seems insufficient and incomplete. Water scarcity is vital when assessing blood metabolites since water availability influences the amount of feed that an animal can consume. Assessment of blood metabolites from goats subjected to water stress is vital to generate data depicting the adaptability of goats to limited water resources. Understanding water stress on the nutritional status of goats gives a platform to understand the extent of adaptability of goats to limited resources.

2.4 Water as a major constraint to goat productivity

Water scarcity is a global topical issue (Arnell, 1999; Mabhaudhi *et al*., 2013; News24, 2014). To highlight water challenges, Arnell (1999) reported ongoing water challenges since an uneven distribution of precipitation exists today due to global warming. This tends to alter wet and warm seasons as years progress. Arnell (1999) also reported that agriculture is one of the industries that will be severely stricken by water shortages since it is projected that by 2025, water supply will be less than what the public needs. This situation is expected to worsen by 2050. For evidence regarding water demands over the next couple of years (see Figure 2.1). In such instances, goats are preferred species since they possess physiological mechanism for regulating water (Adogla-Bessa and Aganga, 2000; Al-Tamimi, 2007; Silanikove *et al*., 2010). Although goats have been reported to withstand water stress, dry seasons cause severe state of dehydration (Adogla-Bessa and Aganga, 2000; Alamer, 2006). Water sites are largely dispersed due to drought (Silanikove,



(Source: Arnell, 1999)

Figure 2.1: Global water demands over six decades (1990 to 2050)

2000). Masikati (2010) reported that goats in Zimbabwe access water point as far as about 14 km from common grazing land. This leaves goats going for days without drinking water since they walk long distances in search for water points, away from grazing areas. In the process, a significant amount of energy is lost on movements instead of consuming feed (McGregor, 2004b; Alamer, 2009).

In Saudi Arabia, water stress has been monitored in indigenous goats (Al-Tamimi, 2007), where the best tolerant breeds to water stress have been selected to suit farmer preferences. Under such environmental conditions, the use of adapted indigenous breeds is relevant. Such characteristics help to ensure conservation of goat genotypes capable of withstanding water scarcity. As such, humans should also adapt to water-saving practices (Mabhaudhi *et al*., 2013; News24, 2014). The southern African region experiences a continued drought, which can pose threat to the livestock industry (Barrios *et al*., 2006). There is, therefore, a need to explore the extent with which indigenous goats found in the southern African region can withstand water stress. To help explore water stress for goats, response of indigenous Nguni goats to water deprivation, water restriction and water salinity, all of which help one to understand the extent of adaptability of goats to water resources, requires investigation. This can be of interest in the quest to ensure conservation of breeds.

2.5 Approach to water challenges in goats

Sub-Saharan regions are water-scarce. Where water points are available, it may contain considerable amounts of dissolved solids that may reduce the quality of water resources for goats (McGregor, 2004a; Alamer, 2009; Masikati, 2010). Such conditions could be stressful to goats, and impact negatively to their productivity since they depend on available input resources to meet daily nutritional requirements. Conditions where water resources are poor in quantity and in quality, goats tend to adapt to their natural water-saving mechanisms (Alamer, 2009). Therefore, farmers that keep Nguni goats under conditions where water resources are scarce need to understand the effects of water deprivation, water restriction and water salinity.

2.5.1 Water deprivation

Goats withstand water scarcity for days since 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 meeting 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. This is necessary to help ensure availability of metabolic water during times where water is scarce. Therefore, subjecting indigenous goats of sub-Saharan Africa to such conditions can help devise means of adaptation to water scarcity. Table 2.3 shows reference values pertaining goat productivity for indigenous goats subjected to varying water deprivation.

2.5.2 Water restriction

The unavailability of sufficient water for goats on a daily basis continues to be a topical issue. Available water points do not meet the daily requirements for goats such that goats need 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 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 feed ingested by the goat. It is, therefore, necessary for goats to maintain the rumen environment even when water supply is limited, as this helps to ensure maximum utilization of feed resources. Several studies pertaining 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; Al-Ramamneh *et al*., 2012). Table 2.4 shows performance of goats subjected to water restriction. The response of Nguni goats to water restriction is not well understood. A series of studies pertaining that ensure understanding of the adaptability of common goat genotypes found in the southern African region to stress factors such as water deprivation and water restriction, including water salinity. This is because, where water resources are insufficient to meet daily requirements for goats, water available for goats are usually saline.

2.5.3 Water salinity

Under drought-stricken areas, available water resources are saline, reducing the quality of

Table 2.3: Intake, growth performance and the nutritional status of indigenous goats subjected to varying levels of water deprivation

Goat productivity	Water deprivation (in hours)					Source
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)
Water to feed ratio	2.6	2.5	1.8	1.5	-	Adogla-Bessa and Aganga (2000)
Growth performance						
Average daily gain (g/day)	85.5	81.9	64.3	65.6	-	Adogla-Bessa and Aganga (2000)
Feed conversion ratio	9.3	9.3	12.1	12.1	-	Adogla-Bessa and Aganga (2000)
Nutritional status						
BCS (1-5 scale)	1.6	-	-	-	-	Rumosa Gwaze *et al*. (2010)
Body weight (kg)	20.0	20.0	20.33	20.5		Abdelatif *et al*. (2010)
FAMACHA scores	-	-	-	-	3	Kaplan *et al*. (2004)
Faecal egg counts (PEG)	-	-	-	-	1372	Kaplan *et al*. (2004)
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 *et al*. (2010)
Urea (mg/dl)	21.42	22.0	23.0	24.0	25.0	Eltayeb (2006)
Cholesterol (mg/dl)	119.21	-	-	-	-	Ihedioha and Agina (2013)

Abbreviations: BSC: body condition scoring

Table 2.4: Intake, growth performance and the nutritional status of indigenous goats subjected to varying levels of water restriction

Goat productivity	Water restriction (%)				Source
Intake	20-40	40-60	60-80	80-100	Abioja *et al*. (2010)
Water intake (mL/d)	715.2	-	1175.3	1398.4	Abioja *et al*. (2010)
Feed intake (g DM/day)	402.8	-	445.8	446.0	Abioja *et al*. (2010)
Water to feed ratio	1.8	-	2.7	3.1	Abioja *et al*. (2010)
Growth performance					
Average daily gain (g/day)	-108.3	-	16.7	27.4	Abioja *et al*. (2010)
Feed conversion ratio	-0.222	-	0.047	0.056	Abioja *et al*. (2010)
Nutritional status					
BCS (1-5 scale)	-	-	-	1.6	Rumosa Gwaze *et al*. (2010)
Body weight (kg)	-	48.3	49.0	49.3	Casamassima *et al*. (2008)
FAMACHA scores	-	-	-	3	Kaplan *et al*. (2004)
Faecal egg counts (PEG)	-	-	-	1372	Kaplan *et al*. (2004)
Glucose (mmol/l)	-	3.1	3.1	3.1	Casamassima *et al*. (2008)
Creatine (µmol/l)	-	102.5	94.6	97.2	Casamassima *et al*. (2008)
Urea (mmol/l)	-	9.7	9.4	8.5	Casamassima *et al*. (2008)
Cholesterol (mmol/l)	-	2.00	1.8	1.7	Casamassima *et al*. (2008)

drinking water for goats. 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 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. One of the principal factors affecting water quality increasing water salinity is the amount of total dissolved salts in water. The presence of dissolved salts in drinking water for animals' drinking water. These include calcium, magnesium, sodium, chlorine, sulphates and hydrocarbons that cause harmful effects resulting in poor performance, illnesses that lead to death (Yape Kii and Dryden, 2005; Maldonado-Valderrama *et al*., 2011). Various goat goats breeds common amongst farmers of the southern African region still needs further understanding, as this may expand the scope of water stress for indigenous goats.

2.6 Summary

The productivity of indigenous goats is influenced by limited input resources such as water. Water challenges are a major threat to the livestock industry since water demands are expected to worsen with time, increasing the competition for water between humans and agricultural activities. Water deprivation, water restriction and water salinity are stress factors that can reduce goat productivity. The objective of the current review was to determine the influence of water stress on feed intake, growth performance and the nutritional status of indigenous goats kept in the southern African region.

2.7 References

Abdelatif, A.M., Elsayed, S.A. and Hassan, Y. M., 2010. Effect of State of Hydration on Body Weight, Blood constituents and urine excretion in Nubian goats (Capra hircus), World Journal of Agricultural Sciences, 6 (2): 178-188.

Abioja, M.O., Osinowo, O.A., Adebambo, O.A., Bello, N.J. and Abiona, J.A., 2010. Water restriction in goats during hot-dry season in the humid tropic: feed intake and weight gain, Annales de Zootechnie 59, 195–203.

Adogla-Bessa, T. and Aganga, A.A., 2000. Responses of Tswana goats to various lengths of water deprivation, South African Journal of Animal Science, 30(1): 87-91.

Aganga, A.A., Adogla-Bessa, T., Omphile U.J. and Tshireletso. K., 2000. Significance of browse in the nutrition of Tswana goats, Archivos de Zootecnia, 49: 469-480.

Alamer, M., 2006. Physiological responses of Saudi Arabia indigenous goats to water deprivation, Small Ruminant Research, 63: 100–109.

Alamer, M., 2009. Effect of water restriction on lactation performance of Aardi goats under heat stress conditions, Small Ruminant Research, 84: 76–81.

Al-Ramamneh, D., Riek A. and Gerken, M., 2012. Effect of water restriction on drinking behaviour and water intake in German black-head mutton sheep and Boer goats, Animal, 6(1): 173–178.

Al-Ramamneh, D., Riek, A. and Gerken, M., 2010. Deuterium oxide dilution accurately predicts water intake in sheep and goats, Animal, 4(9): 1606–1612.

Al-Tamimi, H.J., 2007. Thermoregulatory response of goat kids subjected to heat stress, Small Ruminant Research, 71(1–3): 280–285.

Arnell, N.W., 1999. Climate change and global water resources. Global Environmental Change, 9: S31–S49.

Banda, J.W., Ayoade, J.A., Karua, S.K. and Kamwanja L.A., 1993. The local Malawi goat, World Animal Review, 74(75): 49–57.

Barrios, S., Bertinelli, L. and Strobl, E., 2006. Climatic change and rural–urban migration: the case of sub-Saharan Africa, Journal of Urban Economics, 60: 357–371.

Bengaly, K., Mhlongo, S. and Nsahlai, I.V., 2007. The effect of wattle tannin on intake, digestibility, nitrogen retention and growth performance of goats in South Africa, Livestock Research for Rural Development, 19(4).

Bouwman, A.F., Van der Hoek, K.W., Eickhout, B. and Soenario, I., 2005. Exploring changes in world ruminant production systems, Agricultural Systems, 84(2): 121–153.

Casamassima, D., Pizzo, R., Palazzo, M., D'Alessandro, A.G. and Martemucci, G., 2008. Effect of water restriction on productive performance and blood parameters in comisana sheep reared under intensive condition, Small Ruminant Research 78: 169–175.

Castel, J.M., Mena, Y., Delgado-Pertinez, M., Camunez, J., Basulto, J., Caravaca, F., Guzman-Guerrero, J.L. and Alcalde, M.J., 2003. Characterization of semi-extensive goat production systems in southern Spain, Small Ruminant Research, 47: 133–143.

Chimonyo, M., Bhebhe, E., Dzama, K., Halimani, K. and Kanengoni, A., 2005. Improving smallholder pig production for food security and livelihood of the poor in southern Africa, African Crop Science Conference Proceedings, 7: 569-573.

De Rancourt, M., Fois, N., Lavin, M.P., Tchakerian, E. and Vallerand, F., 2006. Mediterranean sheep and goats production: An uncertain future, Small Ruminant Research 62: 167–179.

Eltayeb, E.E., 2006. Effect of salinity of drinking water and dehydration on thermoregulation, blood and urine composition in Nubian goats, Dissertation (MSc), University of Khartoum, Sudan.

Erasmus, J.A., 2000. Adaptation to various environments and resistance to disease of the Improved Boer goat, Small Ruminant Research, 36: 179-187.

Estrada-Cortes, E., Vera-Avila, H.R., Urrutia-Morales, J., Villagomez-Amezcua, E., Jimenez Severiano, H., Mejía-Guadarrama, C.A., Rivera-Lozano, M.T. and Gamez-Vázquez HG., 2009. Nutritional status influences reproductive seasonality in Creole goats: 1. Ovarian activity during seasonal reproductive transitions, Animal Reproduction Science 116: 282–290.

Grünwaldt, E.G., Guevara, J.C., Estevez, O.R., Vicente, A., Rousselle, H., Alcuten, N., Aguerregaray, D. and Stasi, C.R., 2005. Biochemical and Haematological Measurements in Beef Cattle in Mendoza Plain Rangelands (Argentina), Tropical Animal Health and Production September, 37(6): 527-540.

Hango, A., Mtenga, L.A., Kifaro, G.C., Safari, J., Mushi, D.E. and Muhikambele, V.R.M., 2007. A study on growth performance and carcass characteristics of Small East African goats under different feeding regimes, Livestock Research for Rural Development, 19 (9).

Hassan, M.M. Hoque, M.A., Islam, S.K.M.A., Khan, S.A., Roy, K. and Banu, Q., 2011. A prevalence of parasites in black Bengal goats in Chittagong, Bangladesh, International Journal of Livestock Production, 2(4): 40-44.

Hatendi, P.R., Smith, T., Ndlovu, L. and Mutisi, C., 1992. Fattening mature indigenous (Matabele) goats: effects on animal performance, body and carcass composition, In: Ray, B., Lebbie, S.H.B. and Raynolds, L., Small Ruminant Research and Developments in

Africa, Proceedings of the First Biennial Conference of the African Small Ruminant Research Network, ILRAD, Nairobi, Kenya, 10-14 December, 1990.

Herrera, P.Z., Delgado, J.V., Arguello, A., Camacho, M.E,, Costa, R., 2011. Effects of extensive system versus semi-intensive and intensive systems on growth and carcass quality of dairy kids. Revista Brasileira de Zootecnia, 40: 2613-2620.

Ihedioha, J.I. and Agina, O.A., 2013. Serum biochemistry profile of Nigerian horses (Equus Caballus, Linnaeus 1758), Animal Research International, 10(3): 1826–1833.

Kaplan, R.M., Burke, J.M., Terrill, T.H., Miller, J.E., Getz, W.R., Mobini, S., Valencia, E., Williams, M.J., Williamson, L.H., Larsen, M. and Vatta, A.F., 2004. Validation of the FAMACHA© eye colour chart for detecting clinical anaemia in sheep and goats on farms in the southern United States, Veterinary Parasitology, 123: 105–120.

Ketzis, J., 1997. Methods for establishing and evaluating a goat introduction project, Livestock Research for Rural Development, 9(1).

Kioumarsi, H., Yalaya, Z.S. and Rahman, W.A., 2011. The effect of molasses/mineral feed blocks along with the use of medicated blocks on the haematological and biochemical blood parameters in Boer goats, Asian Journal of Animal and Veterinary Advances, 6: 1264-1270.

Mabhaudhi, T., Modi, A.T. and Beletse, Y.G., 2013. Growth, phenological and yield responses of a Bambara groundnut (Vigna subterranea L. Verdc) landrace to imposed water stress: II. Rain shelter conditions Water South Africa, 39: 191–198.

Madibela, O.R. and Segwagwe, B.V.E., 2008. Nutritional effects of supplementary feeding on maternal blood metabolites, cortisol, thyroid hormones levels and on outcome of pregnancy of dry season kidding Tswana goats, Livestock Research for Rural Development 20:4.

Madziga, I.I., Alawa, C.B.I., Lamidi, O.S. and Goska, D.Y., 2013. Assessing the nutritional status of four indigenous breeds of cattle using some blood metabolites in Nigeria, Journal of Biology, Agriculture and Healthcare, 3(2): 1-8.

Maldonado-Valderrama, J., Wilde, P., Macierzanka, A. and Mackie, A., 2011. The role of bile salts in digestion, Advances in Colloid and Interface Science 165: 36–46.

Maltz, E., Olsson, K., Glick, S.M., Fyhrquist, F., Silanikove, N., Chosniak, I. and Shkolnik, A., 1984. Homeostatic response to water deprivation or haemorrhage in lactating and non lacating Bedouin goats, Comparative Biochemistry and Physiology Part A: Physiology, 77(1): 79–84.

Masikati, P., 2010. Improving the water productivity of integrated crop-livestock systems in the semi-arid tropics of Zimbabwe: an ex-ante anal ysis using simulation modelling. Retrieved January 17, 2012, from http://www.zef.de/fileadmin/webfiles/downloads/zefc_ecology_development/eds_78_masikati_text.pdf.

McGregor, B.A., 2004a. The use and macro-mineral content of saline water for goat production, South African Journal of Animal Science, 34(1): 215-218.

McGregor, B.A., 2004b. Water quality and provision for goats. A report for the Rural Industries Research and Development Corporation. RIRDC Publication No.04/036.Rural Industries Research and Development Corporation, Canberra.

Mengistu, U., Dahlborn, K., and Olsson, K., 2007. Mechanisms of water economy in lactating Ethiopian Somali goats during repeated cycles of intermittent watering, Animal., 1(7): 1009–1017.

Misra, A.K. and Singh, K., 2002. Effect of water deprivation on dry matter intake, nutrient utilization and metabolic water production in goats under semi-arid zone of India, Small Ruminant Research, 46: 159–165.

Moyo, B., Masika, P.J. and Muchenje, V., 2012. Effect of supplementing crossbred Xhosa lop-eared goat castrates with *Moringa oleifera* leaves on growth performance, carcass and non-carcass characteristics, Tropical Animal Health and Production, 44:801–809.

Muna, M.M. and Ammar, I.E., 2001. Effects of water and feed restriction on body weight change and nitrogen balance in desert goats fed high and low quality forages. Small Ruminant Research, 41: 19–27.

Ndlovu, L.R. and Simela, L., 1996. Effect of season of birth and sex of kid on the production of live weaned single born kids in smallholder East African goat flocks in North East Zimbabwe, Small Ruminant Research, 2: 1–6.

Ndlovu, T., Chimonyo, M., Okoh, A.I., Muchenje, V., Dzama, K. and Raats, J.G., 2007. Assessing the nutritional status of beef cattle: current practices and future prospects. African Journal of Biotechnology, 6(24): 2727-2734.

News24, 2014. SA a water-scarce country - Zuma. [Online] Available from: http://www.news24.com/SouthAfrica/News/SA-a-water-scarce-country-Zuma-20141101. [Accessed: 10th November 2015].

Nsoso, S.J., Aganga, A.A., Moganetsi, B.P and Tshwenyane, S.O., 2003. Body weight, body condition score and heart girth in indigenous Tswana goats during the dry and wet seasons in southeast Botswana, Livestock Research for Rural Development, 15(4).

Ogwang, B.H. and Karua, S.K., 1994. The effect of supplements of crop residues and agro-industrial by-products on the growth performance of Swazi goats. In: Lebbie, S.H.B., Rey, B. and Urungu, E.K. (eds), Small Ruminant Research and Development in Africa. Proceedings of the Third Biennial Conference of the African Small Ruminant Research Network, ILRI, Nairobi, Kenya.

Pambu-Gollah, R., Cronje, P. B. and Casey, N. H., 2000. An evaluation of the use of blood metabolite concentrations as indicators of nutritional status in free-ranging indigenous goats, South African Journal of Animal Science, 30(2): 115-120.

Prasetiyono, B.W.H.E., Sunagawa, K., Shinjo A. and Shiroma, S., 2000. Physiological relationship between thirst level and feed intake in goats fed on alfalfa hay cubes, Asian-Australasian Journal of Animal Science, 13: 1536-1541.

Rumosa Gwaze, F., Chimonyo, M. and Dzama, K., 2009. Communal goat production in Southern Africa: A review, Tropical Animal Health and Production, 41: 1157–1168.

Rumosa Gwaze, F., Chimonyo, M. and Dzama, K., 2010a. Nutritionally-related blood metabolites and faecal egg counts in indigenous Nguni goats of South Africa, South African Journal of Animal Science, 40 (5): 480-483.

Rumosa Gwaze, F., Chimonyo, M. and Dzama, K., 2010b. Relationship between nutritionally-related blood metabolites and gastrointestinal parasites in Nguni goats of South Africa, Asian-Australasian Journal of Animal Sciences, 23(9): 1190-1197.

Sebsibe, A., Casey, N.H., van Niekerk, W.A., Tegegne, A. and Coertze, R.J., 2007. Growth performance and carcass characteristics of three Ethiopian goat breeds fed grain less diets varying in concentrate to roughage ratios, South African Journal of Animal Science, 37(4): 221-232.

Shackleton, C.M., Shackleton, S.E. and Cousins, B., 2001. The role of land-based strategies in rural livelihoods: the contribution of arable production, animal husbandry and natural resource harvesting in communal areas in South Africa, Development Southern Africa, 18(5): 581-604.

Shrestha, J.N.B. and Fahmy, M.H., 2005. Breeding goats for meat production: a review 1. Genetic resources, management and breed evaluation, Small Ruminant Research 58: 93–106.

Sibanda, L.M., Ndlovu, L.R. and Bryant, M.J., 1997. Effects of feeding varying amounts of a grain/forage diet during late gestation and lactation on the performance of Matebele goats, Journal of Agricultural Science, 128, 469-477.

Silanikove, M., 2000. The physiological basis of adaptation in goats to harsh environments, Small Ruminant Research, 35(3): 181–193.

Silanikove, N., Leitner, G., Merinc, U., Prosser C.G., 2010. Recent advances in exploiting goat's milk: Quality, safety and production aspects, Small Ruminant Research, 89: 110-124.

Tolera, A., Merkel, R.C., Goetsch, A.L., Sahlu, T. and Negesse, T., 2000. Nutritional constraints and future prospects for goat production in East Africa, Opportunities and Challenges of Enhancing Goat Production in East Africa, Conference held at Debub University, Awassa, Ethiopia, November 10-12, 2000, pages 43–57.

Yape Kii, W. and Dryden, G.McL. 2005, Effect of drinking saline water on food and water intake, food digestibility, and nitrogen and mineral balances of rusa deer stags (Cervus timorensis russa), Animal Science, 81: 99–105.

Chapter 3: Opportunities for improving the contribution of Nguni goats to rural livelihoods for resource-poor farmers in semi-arid environments

(This manuscript is under review at Journal of Agricultural Science and Technology)

Abstract

Goats are important when improving production opportunities amongst resource-poor farmers, since goats are largely kept under communal production systems in southern Africa. The objective of the study was to determine goat production opportunities that contribute to farmers' livelihoods using Nguni goats reared by resource-poor farmers from semi-arid areas. A cross-sectional survey was conducted to 135 farmers that keep goats from Jozini municipality of uMkhanyakude district. Goat ownership was largely by female farmers. Goats largely grazed communally. Farmers also ranked keeping goats for household consumption as most important, followed by generating household income. Farmers ranked keeping goats for skins as more important than milk production. Female farmers were likely to face water challenges ($P < 0.05$). On the other hand, male farmers were more likely to face feed challenges than female farmers. It was concluded that the productivity of goats can be improved by enhancing nutrition for goats, as this has a potential to improve farmer opportunities.

Keywords: Nguni goats, opportunities, input resources, constraints.

3.1 Introduction

In southern Africa, goats are largely kept by resource-poor farmers. In South Africa, goats are estimated at 861.9 million (Aziz, 2010), and are largely kept under communal production systems. Over 95 % of goats kept under communal production systems are adapted indigenous breeds (King, 2009). Even though goats are dominant under communal production systems compared to the commercial set-up, their contribution to the national economy is low. Goats are normally referred to as the “poor man’s cows” (Ribeiro and Ribeiro, 2010), and are an alternative to farmers that cannot afford to keep cattle. Goats are easy to maintain, making them suitable for farmers that largely depend on livestock for livelihoods. Women and children, who are the majority in rural communities, have easy access to goats. Therefore, goats can be used as tools to ensure socio-economic development of rural areas (Botha and Roux, 2008).

Marginalised conditions such as water and feed resources available in poor quantity and quality in most communal production systems make goats suitable, especially where grazing land is limiting (Rumosa Gwaze *et al.*, 2009). Goats adapt with ease to such marginal conditions due to their small forage requirements compared to cattle. In addition, goats easily survive on degraded lands, and prefer browsing to grazing. Furthermore, they are hardly treated against diseases and parasites (Erasmus, 2000; Lehloenya *et al.*, 2005; Rumosa Gwaze *et al.*, 2009). Browse is usually more than grass in degraded environments. The goats are hardy and have good mothering ability as well. In that regard, goats can be considered as an important tool that can be used to create wealth amongst the poor. This is vital to consider in countries stricken by poverty, malnutrition and unemployment, coupled with exponentially growing human population (King, 2009).

For years, goat improvement programmes have been based on imported breeds which have large frame size, and are fast growing (Mapiye *et al.*, 2009). Such programmes have been fuelled by the preference for fast growing goats and high milk production (Ahuya *et al.*, 2005). Use of imported breeds ignores ability of resource-poor farmers to afford the high input requirements, and the harsh environmental conditions that obtain in communal production systems. Since indigenous goat genotypes can survive under feed shortages, the should form the core of wealth creation programmes to best suit resource-poor farmers (Meigh *et al*., 1999; Ngwa *et al*., 2000; Rumosa Gwaze, 2009).

To enhance sustainability, the profitability of goats should be achieved through participatory approaches. Involving farmers from the onset, allows for easier adoption and implementation of wealth creation programmes that benefit the poor. Opportunities for creating wealth using goats have not received adequate attention. Factors that influence goat productivity, should, therefore, be explored. Hence, it is necessary to develop models that can be used to assess the potential of indigenous goats as a gateway to food security. The objective of the current study was to determine opportunities for wealth creation using Nguni goats kept by resource-poor farmers.

3.2 Materials and methods

3.2.1 Study site and ethical clearance

The study was conducted at Jozini municipality of uMkhanyakude district in the KwaZulu-Natal province of South Africa. The study was in compliance with the standards required by the Animal Ethics Committee of the University of KwaZulu-Natal (Reference No.: HSS/1377/013D). Jozini municipality lies 27º 24' 06.9' S; 32º 11' 48.6 E (Gush, 2008), and covers about 3 082 km^2, with an altitude ranging from 80 to 1900 m above sea level. Jozini experiences subtropical climate, with an average annual rainfall of 600 mm. Average daily maximum and minimum temperatures at Jozini read 20 ºC and 10 ºC, respectively. The vegetation type of the area is mainly coastal sand-veld, bush-veld and foothill wooded grasslands (Morgenthal *et al*., 2006). Agricultural practices of the people in this district include production of field crops, vegetables and raising livestock extensively.

3.2.2 Farmer selection and design

A list of farmers keeping goats from each community was compiled with the help from extension officers, veterinary assistants, and youth representatives. Five communities were visited across Jozini namely; Mamfene, Maphaya, Mthambalala, Mkhoyana and Biva. The five communities were randomly selected amongst communities active in goat production. A total of 135 households were interviewed across the 5 communities visited.

3.2.3 Data collection

Data from farmers were collected through interviews using pre-tested questionnaires and by direct observations by the researcher. In each community, scheduled meetings with local authorities such as chiefs and local headmen were arranged to gain access to communities. Opportunities and constraints to goat production were discussed by the researcher through focus group discussions with key informants in the community. These included chiefs, headmen, traditional healers, teachers, elders and local political leaders. The selection of households was based on the willingness of the farmers to participate in the study. Questionnaires were administered in the local vernacular Zulu language.

Data collected included household demographics, farmer opportunities, including goat production constraints. Watering and feeding systems practised by farmers were captured. In addition, data regarding whether farmers milk goats or not were also captured.

3.2.4 Statistical analyses

The PROC FREQ of SAS (2010) was run to compute household demographic profiles, milk attributes and production constraints, including uses of goat products and production opportunities. PROC MMEANS of SAS (2010) were also used to calculate mean ranks for importance of livestock and reasons for keeping goats and product farmers' value from goats. The General Linear Models of SAS (2010) was used to analyse farmers' goat herd composition. The Chi-square test of SAS (2010) was used to analyse for associations between milk attributes and goat production constraints. PROC LOGISTIC of SAS (2010) was used to compute odds ratios that influence resource availability for goats (water and feed).

3.3 Results

3.3.1 Farmer socio-economic profiles

Household demographics amongst farmers are given in Table 3.1. Goat ownership was largely by females. Most respondents reside on farm. Youth participation on goat rearing activities was huge. This involves assisting in feeding, heading, slaughtering of goats, meat sales, construction of pens and penning of goats at night. Most households lived under R2000 per month, and were considered as poor. Also, farmers largely practiced scavenging compared to the backyard production system. Farmers did not practice semi-intensive or intensive production system.

Table 3.1: Socio-economic characteristics of respondents (%) from Jozini

Household demographic parameter		Percentage (n = 135)
Goat ownership	Male	23.7
	Female	67.4
	Children	8.9
Marital status	Married	54.1
	Not married	45.9
Educational status	No formal education	45.2
	Formal education	54.8
Religious belief	Tradition	54.8
	Christianity	45.2
Household head residence	On farm	58.5
	Away from farm	41.5
Farmer principal occupation	Unemployed	20.0
	Formally employed	23.7
	Informally employed	20.0
	Pensioners	36.3
Youth participation on goats	Active	68.9
	Not active	31.1
Household income per month	R0 – R1000	31.1
	R1001 – R2000	43.1
	Greater than R2000	25.9
Wealth status of households	Very poor[1]	12.6
	Poor	52.6
	Less poor	34.8
Production system	Scavenging production system	75.6
	Backyard production system	24.4

[1] Very poor farmers consisted of farmers with few goats, chickens and meagre amounts of income. Poor farmers were those with some reliable sources of income, at least 2 cows and owning other forms of livestock. Less poor households had at one household member with a formal employment or have large livestock herds/flocks.

3.3.2 Livestock importance, goat herd composition and reasons for keeping goats

The importance of goats to farmers and goat products that farmers value most are shown in Table 3.2. Cattle were ranked as most important species, followed by goats. Respondents ranked keeping goats for chevon as most important. Skins were ranked second, whilst milk and manure were ranked last. Goat flock composition is shown in Table 3.3. Lactating does, non-lactating does, kids, breeding males and castrates all varied with flock size (*P* <0.05), except for breeding males. Adult goats were categorized as lactating and non-lactating females, breeding females, breeding males, and castrates. Reasons farmers keep goats are illustrated in Figure 3.1. Farmers ranked keeping goats for household consumption as most important, followed by needs to raise household income, then pride and status. Rearing goats for cultural purposes to ensure savings and investment were ranked the same, whilst rearing goats for manure was ranked least.

3.3.3 Roles of household member on goat management

The Roles of household member on goat management are shown on Table 3.4. Female farmers were the major role players with regards to feeding practices. Mating, health and purchasing of goats were a role by male farmers. Children and male farmers were largely responsible for slaughter of goats. Female farmers were largely responsible for meat sales. Construction of pens and penning of goats at night was largely a role played by the children and male farmers.

3.3.4 Milk attributes and goat production constraints

Goat mortalities were indicated as the highest challenges to income generation from goats, and were associated with farmers being discouraged from milking (P >0.05). Also, farmers indicated

Table 3.2: Importance of livestock (mean ranks) kept and goat product value by farmers in Jozini

Livestock species kept	Rank (mean rank)[a]
Cattle	1 (1.13)
Goats	2 (1.77)
Sheep	5 (4.00)
Pigs	4 (3.86)
Poultry	3 (2.44)
Value of goat products	Rank (mean rank)
Milk	3 (3.31)
Meat	1 (1.18)
Skins	2 (2.75)
Manure	4 (4.25)

Table 3.3: Mean (± SE) herd composition as influenced by herd size

Goat herd composition	Herd size (± SEM)	
	Small	Large
Lactating does	2.0 ± 0.17[a]	4.8 ± 0.24[b]
Non-lactating does	1.1 ± 0.15[a]	3.1 ± 0.21[b]
Kids	8.5 ± 0.81[a]	17.2 ± 1.16[b]
Breeding females	3.1 ± 0.20[a]	7.9 ± 0.28[b]
Breeding males	0.5 ± 0.11[a]	1.2 ± 0.15[b]
Castrates	1.0 ± 0.22[a]	3.4 ± 0.31[b]

[a, b] Within a row, values with the different superscripts differ ($P < 0.05$)

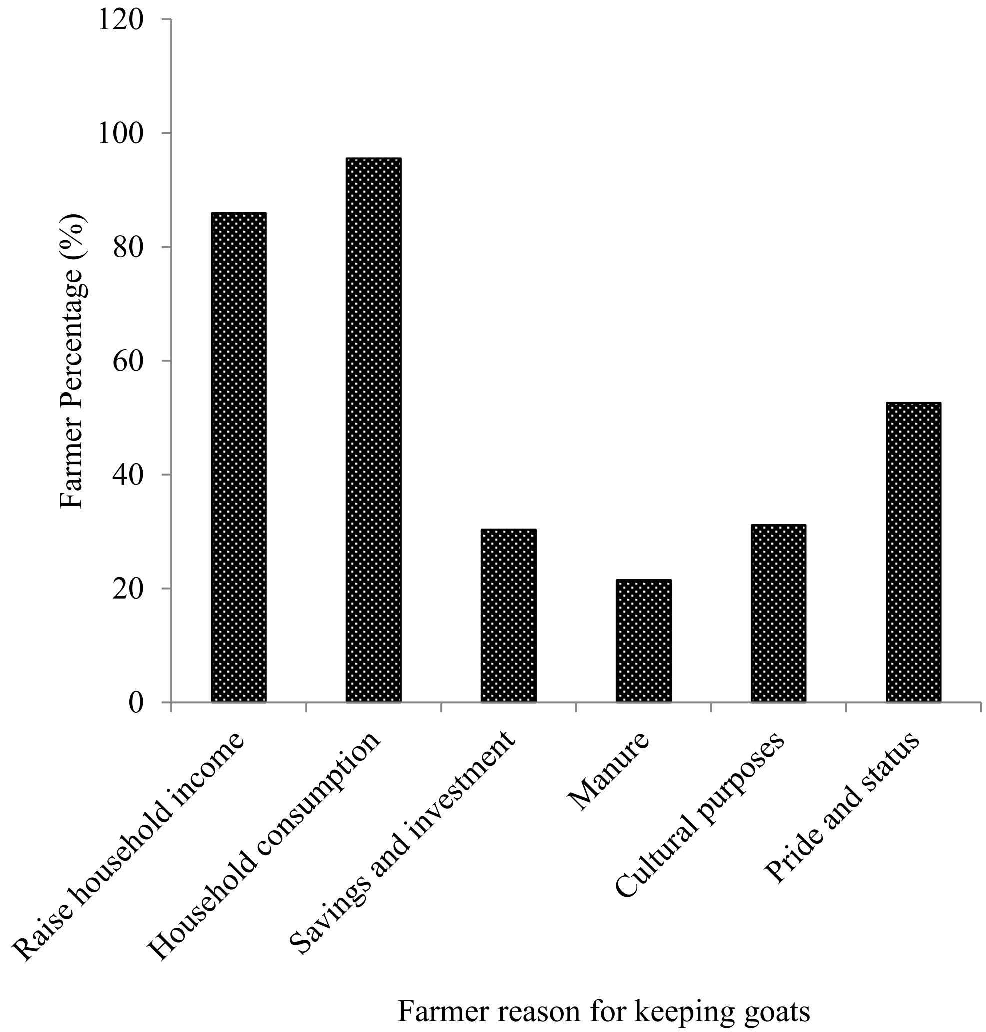


Figure 3.1: Reasons for keeping goats

Table 3.4: Roles of household members on goat management in Jozini

Role of household	Gender of household member		
	Adult male	Adult female	Children
Feeding	28.7	48.5	22.8
Penning	32.3	11.9	55.8
Kraal construction	59.0	11.2	29.9
Mating management	63.7	25.0	11.3
Health management	61.2	23.9	14.9
Purchasing	69.4	25.4	5.2
Slaughtering	41.0	6.0	53.0
Selling	15.9	48.4	35.7

that they do not know goats can be milked, and was associated with that, male farmers are not aware of the value of goat milk (*P* <0.01). Quite a large number of farmers indicated they were not aware of the value of goat milk they largely value meat from goats (*P* <0.01). Also, most farmers did not want to milk goats, and was associated with that farmers are used to milking cows (*P* <0.05). Most farmers indicated they prefer cow milk compared to goat milk, and was associated to that farmers are used to cow milk (*P* <0.01). Challenges that hinder farmers from milking were largely that farmers have never seen goats being milked, and were associated with that farmers prefer cow milk over goat milk (*P* <0.05). Lastly, farmers indicated they are faced with water and feed resource shortages for goats, and were both associated with youth being active in goat rearing activities (P >0.05) and (P <0.5), respectively.

Odds ratio estimates for farmers experiencing water and feed resource challenges are shown in Table 3.5. Female farmers were more likely to face water shortages than male farmers. Farmers that reside away from the farm were likely to lack water resources for goats. Also, farmers practising backyard production system experienced water challenges. Male farmers were more likely to face feed shortages than female farmers. Farmers that reside away from farm were likely to face feed resource challenges. Households having youth participating in goat rearing activities faced feed resource challenges. Farmers practising scavenging production systems were projected to likely experience feed resource challenges.

3.3.5 Uses of goat products and production opportunities

Uses of goat products and production opportunities are shown on Table 3.6. The majority of farmers indicated they did not use goat milk. Farmers also indicated they largely use chevon for

Table 3.5: Odds ratio estimates for farmers experiencing water and feed resource challenges

Water and feed challenges	Odds ratio	Lower CI	Upper CI
Water shortage challenges			
Gender of farmer (male vs female)	0.936	0.420	2.084
Farmers residing on farm (yes vs no)	1.461	0.630	3.385
Youth participation in goats (yes vs no)	0.846	0.400	1.790
Production system (scavenging vs backyard)	0.756	0.339	1.688
Feed shortage challenges			
Gender of household head (male vs female)	3.410	0.684	17.00
Farmers residing on farm (yes vs no)	0.489	0.141	1.691
Youth participation in goats (yes vs no)	8.029	1.000	64.46
Production system (scavenging vs backyard)	2.416	0.493	11.85

CI: confidence interval

Table 3.6: Uses of goat products and production opportunities for farmers in Jozini

	Uses of goat product			
Goat product	Consumption	Sale	Exchange	Other
Milk	10.4	4.4	5.9	79.3
Meat	83.7	11.6	1.5	3.0
Skin	0	18.5	59.3	22.2
Manure	0	3.0	35.6	61.4
	Production opportunities			
Farmer perception	Option 1	Option 2	Option 3	Option 4
Improving income generation from goat products	77.8	4.4	12.6	5.2
Overcome goat milking challenges	31.1	15.6	18.5	34.8
Improvement of household milk	19.3	17.8	52.6	10.4

Description of terms used:
Other: Includes that farmers do not use goat milk, use for medicinal purposes or to feed kid-lings, using chevon to feed pets, cats and dogs, using skins for decoration or to serve as traditional attire, and using manure as fertilizer in home gardens.

For perceptions pertaining improving income generation from goat products:
Option 1: selling to make money, Option 2: no idea, Option 3: keeping goats in good health, Option 4: keep many goats

For perceptions concerning overcoming goat milking challenges:
Option 1: educating farmers about goat milk, Option 2: no idea, Option 3: assistance from government with vaccines to keep goats healthy, Option 4: development of camps to aid good better input resources.

For perceptions concerning the improvement of household milk from goats:
Option 1: do not know about goat milk, Option 2: equipping farmers with knowledge about goat milk, Option 3: improving the nutrition of goats, Option 4: keep many goats if farmers milk.

household consumption rather than selling or any other purpose. Goat skins and manure were reported as largely used for exchange by farmers. Respondents viewed selling goat products as best means of generating income from goats. Farmers indicated educational programmes as most effective strategies towards overcoming challenges of milking does. At the same time, farmers perceived being educated about goat milk, and the development of camps for better nutrition can help improve milk production and cash returns from goats. Lastly, farmers perceived assistances by the government and relevant stakeholders regarding supply of water and feed resources for goats would help improve milk production amongst rural residents.

3.4 Discussion

The findings that women owned more goats compared to men could be related to that women care for and value small animals since they are easy to handle (Peacock, 2005). Therefore, it is wise to consider female farmers when designing food security programmes in communal production systems since women seem to care for small animals. Another factor to consider is that, female farmers are able to assist in availing forage for animals during times at which feed is limiting on communal rangelands (Dessie and Ogle, 2001). The finding that most households were characterised as poor in the current study were in agreement with that, communal residents in sub-Saharan Africa are characterised by poverty and unemployment, and live under 1 UDS per day (Chimonyo *et al*., 2005). Youth participation in livestock rearing activities such as that observed reported in the current study helps to foresee the future of sustainable agriculture (Madzimure *et al*., 2012), since rearing experiences may be passed on to new generations by elders. Youth participation in goat rearing activities is desirable in subsistence farming, and can be fuelled by sharing possible benefits such as cash returns from sales.

Since cattle have been viewed as most important livestock species to resource-poor farmers in the current study, goats are an alternative for farmers that cannot afford to keep cattle (Ribeiro and Ribeiro, 2010). Farmers keep goats for various purposes similar to those cattle are kept for such as meat, milk, skins, manure, cash and socio-cultural uses (Donkin and Boyazoglu, 2000; Masika and Mafu, 2004). Superiority of cattle over goats could be due to household status as a sign of wealth, overlooking the maintenances of large animals reared. It is widely known that goats are ideal for resource-poor farmers facing the scarcity of input resources, hence goats are known as "poor man's cow" (Ribeiro and Ribeiro, 2010). This is because that, goats adapt with ease to integrated production systems where input resources such as feeds are limiting (Rumosa Gwaze *et al*., 2009).

Goats have short generation intervals and easy to manage, and contribute with 11 % of total meat produced in sub-Saharan countries (Lebbie, 2004; King, 2009). Goats can, therefore, help ease daily demands for meat influenced by the ever-increasing human population. Since farmers ranked rearing goats to raise income as most important in the current study, such numbers represent the unavailability of formal markets. This results to limited understanding of the contribution of goats to the overall livelihoods of the poor. The contribution of goats to household nutrition and wealth creation can be quantified if farmers can efficiently utilize sellable goat products. Introduction formal markets to resource-poor farmers can, therefore, improve wealth and job creation. Such systems may reduce rural-urban migration. In most households, men migrate to nearby urban areas, leaving homesteads largely managed by their spouses (Tefera, 2007). This leaves women responsible for most activities, meaning the day to day management of homesteads, including caring for livestock. In the current study, female were responsible for feeding and selling meat in goat production. Considering such efforts, women are still given little or no credit regarding livestock practices and their contribution to household economy. The finding that male farmers were responsible for purchasing goats and mating practices can be linked to males making decisions regarding goat productivity.

The limited utilization of goat milk could be linked to the fact that goat milk being is considered as an alternative to cow milk when consumers have developed allergies to cow milk (Ribeiro and Ribeiro, 2010). This disregards the potential for goat milk as a product that can be sold and used as common main source of protein; hence farmers rarely milk goats. In that regard, it is necessary to develop awareness programmes that could enable farmers realize the value of goats to ensure household food security and improve income generation. Fulfilling knowledge dissemination to farmers about goat milk across generations can ensure continued access to high quality protein by the poor, considering that protein consumption is vital for children.

Also, goat milk contains high quality nourishment, provides health and nutritional benefits due to lack of allergies on people (Ribeiro and Ribeiro, 2010). Since goat milk is a fundamental feed source, richer than cow milk in nutritional composition (Silanikove *et al*., 2010), its economic value can be recognised when farmers understand the role of goat milk to the nutrition of consumers. For example, Zeng (1996) found goat milk to contain about 3.14 % fat and 2.66 % protein, and cow milk to contain about 3.09 % fat and 2.39 % protein. In the current study, farmers perceived that goat milk has no financial benefit it is produced in small amounts compared to milk from cattle. Similar findings were observed by Masika and Mafu (2004). This limits farmers to view goat products such as milk as tools with a potential to improve income generation if goat milk can be converted into sellable products such as sour milk. For example, the French goat industry converts goat milk into cheese, which has market demand (Dubeuf *et al*., 2004). In sub-Saharan countries, this can be done by processing goat milk into sour milk which forms part of the staple food amongst rural residents (Masika and Mafu, 2004). By so doing, goat products can largely be available in local markets. Also, understanding of the value of goat milk to the health of consumers may as well improve buying potential from consumers apart from considering quantities.

The finding that households practising scavenging production system were likely to face water resource challenges in the current study could be due to lack of input resources (Chimonyo, 2005; Rumosa Gwaze *et al*., 2009). This is because farmers that practise scavenging production system solely depend on available input resources from veld, without supplementing during times of short supply (Chimonyo, 2005). The finding that male farmers were likely to face feed shortages for goats could be linked with their care for large animals, including the usual migration for work purposes (Dixon, 1982; Peacock, 2005). This results in limited monitoring with regards to basic resources that goats need to increase productivity. This is important to consider because, resource availability to goats helps improve the productivity of goats (Meigh *et al*., 1999; Ahuya *et al*., 2005; Lehloenya *et al*., 2005).

The low consumption of goat milk ignores the fact that goat milk essential to the nutrition of communal residents where protein consumption per capita is very low (Masika and Mafu, 2004; Silanikove *et al*., 2010). This is important considering that milk is accessible to communal residents for most of the year compared to chevon. Areas that milk goats in sub-Saharan countries largely use milk as sour milk, known to be popular product across poor communities. At the same time, goat milk comes in small amounts (Masika and Mafu, 2004), discouraging farmers to consider goat milk for sale. Lack of knowledge about goat milk influences farmer benefits, as farmers in the current study perceived. The fact that goat production systems are characterised by limited input resources, the productivity of goats is affected (Meigh *et al*., 1999; Ahuya *et al*., 2005; Lehloenya *et al*., 2005). Since farmers also thought good nutrition can help maximize goat productivity and maximize cash returns, beyond the scope of home consumption. Such input resources were said to largely be water and feed resources that can be sourced from nearby areas. Similarly with the current study, such responsibilities under communal production systems are skewed towards female farmers since they are largely responsible for feeding practices for goats. By so doing, goats can be economically viable to resource-poor farmers.

3.5 Conclusions

Female farmers were largely active in goat rearing, and are major role players in feeding practices. Lack of knowledge amongst farmers regarding the importance of goat milk, including the fact that goats produce milk in small amounts all influence that potential of goat milk to be considered for sale, thereby limiting farmer opportunities and income generation. Lack of water and feed resources were major challenges that directly influence farmer livelihoods. Therefore, the productivity of goats can be improved by enhancing input resources such as drinking water for goats, which, in turn, has a potential to improve farmer opportunities benefits though sales of goat products. It is, therefore, vital to consider such factors as they lay a platform of ensuring implementable food security and wealth creation programmes for the poor residing in rural areas.

To help farmers adapt to challenges, measures of water stress (water deprivation, water restriction and water salinity) can be used to devise adaptation strategies for indigenous goats that farmers can practice to withstand drought.

3.6 References

Ahuya, C.O., Okeyo, A.M., Njuru, M. and Peacock, C., 2005. Developmental challenges and opportunities in the goat industry: The Kenyan experience, Small Ruminant Research, 60: 197–206.

Botha, A.F. and Roux, J.A., 2008. Fibre, yarn and fabric properties of South African indigenous goat hair. 4th International Cashmere/wool Technique Symposium. Erdos City, China, 17-18 November, pages 140-147.

Chimonyo, 2005. Evaluation of the production and genetic potential of indigenous Mukota and their crosses with Large White pigs in Zimbabwe, Dissertation (PhD), University of Zimbabwe, Harare, Zimbabwe.

Chimonyo, M., Bhebhe, E., Dzama, K., Halimani, K. and Kanengoni, A., 2005. Improving smallholder pig production for food security and livelihood of the poor in southern Africa, African Crop Science Conference Proceedings, 7: 569-573.

Dessie, T. and Ogle, B., 2001. Village poultry production systems in central highland of Ethiopia, Tropical Animal Health and Production, 33, 521-537.

Dixon, R.B., 1982. Women in agriculture: counting the labour force in developing countries, Population and Development Review, 8: 539-566.

Donkin, E.F., Boyazoglu, P.A., 2000. Milk production from goats for household and small-scale farmers in South Africa. In: Proceedings of the Seventh International Conference on Goats, vol.1, Tours, France, pages 324–328.

Dubeuf, J.P., Morand-Fehr, P. Rubino, R., 2004. Situation, changes and future of goat industry around the world, Small Ruminant Research, 51: 165–173.

Erasmus, J.A., 2000. Adaptation to various environments and resistance to disease of the Improved Boer goat, Small Ruminant Research, 36: 179-187.

Gush, M., 2008. Measurement of water use by *Jatropha curcas L.* using the heat pulse velocity technique, Water South Africa, 34 (5): 579–583.

King, F.J.M., 2009. Production parameters for Boer goats in South Africa, Dissertation (MSc), University of the Free State, Bloemfontein, Republic of South Africa.

Lebbie, S.H.B., 2004. Goats under household conditions, Small Ruminant Research, 51: 131–136.

Lehloenya, K.C., Greyling, J.P.C. and Schwalbach, L.M.J., 2005. Reproductive performance of South African indigenous goats following oestrous synchronization and AI, Small Ruminant Research, 57: 115–120.

Madzimure, J., Zander, K.K., Dzama, K. and Chimonyo, M., 2012. Farmer perceptions of classical swine fever outbreak in communal pig production systems of South Africa, African Journal of Agricultural Research, 7(43): 5819-5826.

Mapiye, C., Chimonyo, M., Dzama, K., Raats, J.G. and Mapekula, M., 2009. Opportunities for improving Nguni cattle production in the smallholder farming systems of South Africa, Livestock Science, 124: 196–204.

Masika, P.J. and Mafu, J.V., 2004. Aspects of goat farming in the communal farming systems of the central Eastern Cape, South Africa, Small Ruminant Research, 52: 161–164.

Meigh, J.R., Mckenzie, A.A. and Sene, K.J., 1999. A grid-based approach to water scarcity estimates for eastern and southern Africa, Water Resources Management, 13: 85–115.

Morgenthal, T.L., Kellner, K., van Rensburg, L., Newby, T.S., van derMerwe, J.P.A., 2006. Vegetation and habitat types of the UMkhanyakude Node, South African Journal of Botany, 72: 1–10.

Ngwa, A.T., Pone, D.K., Mafeni, J.M., 2000. Feed selection and dietary preferences of forage by small ruminants grazing natural pastures in the Sahelian zone of Cameroon, Animal Feed Science and Technology, 88: 253-266.

Peacock, C., 2005. Goats: a pathway out of poverty, Small Ruminant Research 60: 179–186.

Ribeiro, A.C. and Ribeiro, S.D.A., 2010. Specialty products made from goat milk, Small Ruminant Research, 89: 225–233.

Rumosa Gwaze, F., 2009. Communal Production Systems of Goats Raised by Resource-Poor Farmers in the Eastern Cape Province of South Africa, Dissertation (PhD), University of Fort Hare, Alice, Republic of South Africa.

Rumosa Gwaze, F., Chimonyo, M. and Dzama, K., 2009. Communal goat production in Southern Africa: A review, Tropical Animal Health and Production, 41: 1157–1168.

SAS, 2010. SAS/STAT Software Release 9.3. SAS Institute Inc., Cary, North Carolina, USA.

Silanikove, N., Leitner, G., Merinc, U., Prosser C.G., 2010. Recent advances in exploiting goat's milk: Quality, safety and production aspects, Small Ruminant Research, 89: 110–124.

Tefera, T., 2007. Improving women farmers' welfare through a goat credit project and its implications for promoting food security and rural livelihoods, Journal of Rural and Community Development, 2: 123-129.

Zeng, S.S., 1996. Comparison of goat milk standards with cow milk standards for analyses of somatic cell count, fat and protein in goat milk, Small Ruminant Research, 21: 221-225.

CHAPTER 4: Influence of water deprivation period on intake and growth performance of Nguni goats

(This manuscript has been accepted in Tropical Animal Health and Production)

Abstract

The objective of the study was to determine the influence of varying periods of water deprivation on intake and growth performance of Nguni goats. A total of 36 Nguni does (initial weight (18±3.2 kg) were used in the study. The goats were housed in individual cages and subjected to varying periods of water deprivation (0; 24; 48 h), with *ad libitum* access to *Medicago sativa* hay. Average daily water intake (ADWI), average daily feed intake (ADFI), water to feed ratio (WFR), average daily gain (ADG) and feed conversion ratio (FCR) were determined weekly. The average daily water intake (ADWI) was largest from goats deprived of water for 48 h compared to those deprived of water for 24 h and 0 h (P <0.05). The ADWI was the same amongst goats deprived of water for 0 h and 24 h (P <0.05). The average daily feed intake (ADFI) was largest for goats deprived of water for 48 h compared to those deprived of water for 24 h and 0 h in week 1 and week 4 of the feeding period (P <0.01). In week 2 and 3 of the feeding period, ADFI was smallest for goats deprived of water for 0 h compared to those deprived of water for 24 h and 48 h (P <0.01). The ADG and FCR declined as the water deprivation period was increased (P <0.01). Water deprivation period resulted in weak negative correlations amongst all parameters tested. It was concluded that water deprivation increased water and feed intake, whereas average daily gain and feed conversion declined as the water deprivation period was increased, thereby impacting on the productivity of Nguni goats.

***Key words*:** water deprivation, goats, intake, growth performance

4.1 Introduction

In Africa, goats are an integral part of small-holder farming systems. Goats make a significant contribution towards farm income, including the stability of subsistence agriculture (Tshabalala *et al*., 2003; Akingbade *et al*., 2004). In developing countries, goats are largely kept under communal production systems by resource-poor farmers, where indigenous genotypes form the majority (Botha and Roux, 2008). Resource-poor farmers are characterized by lack of input resources. These farmers largely depend on indigenous genotypes such as the Nguni known to thrive well under harsh conditions (Pirisi *et al*., 2006; Rumosa Gwaze *et al*., 2009). Goats are fast growing and have shorter generation intervals (Lehloenya *et al*., 2005; Rumosa Gwaze *et al*., 2009). Also, goats have the ability to minimize water losses through various water-saving mechanisms, making them ideal under systems where water resources are limiting (Alamer, 2009). Such characteristics are vital since feed intake, including growth performance are goat productivity indices influenced by the availability of drinking water to the goats (Adogla-Bessa and Aganga, 2000).

Goats sometimes access water points as far as 14 km away from grazing areas (Masikati, 2010). Such factors leave goats without water for days, raising a need for economizing available water resources (Misra and Singh, 2002). The unavailability of water resources for goats impacts directly on their productivity since goats need sufficient drinking water to satisfy their daily physiological requirements. Therefore, there is a need to monitor intake and growth performance of goats subjected to varying periods of water deprivation since farmers largely depend on available input resources to aid maximum goat productivity. Understanding water and feed intake, including growth performance of Nguni goats subjected to varying periods of water deprivation can help in understanding the extent of adaptability of indigenous goats to limited water resources. This study can also help farmers understand thresholds that Nguni goats can tolerate unavailability of water resources so that outcomes from the current study can be adopted by farmers where applicable. By so doing, the stability of subsistence agriculture can be conquered. Also, the potential of goats to survive prolonged periods of water deprivations ensures that goats can utilize feed resources far away from water points using body water reserves. The objective of the current study was to determine the influence of water deprivation on intake and growth performance of Nguni goats. It was hypothesized that, water deprivation influences intake and growth performance of Nguni goats.

4.2 Materials and Methods

4.2.1 Study site and ethical consideration

The experiment was conducted at Ukulinga Research farm in Pietermaritzburg, South Africa. The farm lies 29°40′ S, 30°24′ E with an elevation of about 775 m above sea level. Daily temperatures average 30 °C. Mean annual rainfall is 748.5 mm, falling mostly in summer with light to moderate frost occurring occasionally in winter (Akingbade *et al*., 2001). The experiment was conducted in compliance with the standards required by the Animal Ethics Committee of the University of KwaZulu-Natal (Reference No. 072/14/Animal).

4.2.2 Goat management, diets and experimental design

A total of 36 Nguni does ranging from 9 to 31.5 kg, averaging (18 ± 3.2 kg) were de-wormed with 2 mL of Zolvix Monepantel® (Novartis Animal Health, Australia) and confined in individual pens. Goats were confined in pens during the experimental period for 38 days, where

10 days was allowed for adaptation. Goats were subjected to three varying water deprivation periods (0, 24 and 48 h). Goats were fed on *Medicago sativa* hay purchased from TKW Agriculture Ltd (Pietermaritzburg, South Africa). The hay was chopped to pass through a 5 cm screen. Feed was offered *ad libitum*. Xazela *et al*. (2012) reported that, *Medicago sativa* hay is sufficient to meet the maintenance and growth requirements of goats. The chemical composition of the hay is given in Table 4.1. Water was offered *ad libitum* as well using 10 litre buckets. To monitor water deprivation, a set of goats had unlimited access to drinking water for the entire experimental period (treatment one: T_1). Another set of goats had unlimited access to drinking water for 24 h, followed by a 24 h period of water rehydration (treatment two: T_2). The last set of goats also had unlimited access to drinking water for 48 h, followed by a 24 h period of water rehydration (treatment three: T_3) (Alamer, 2006). There were twelve goats allocated to each of the three treatments. Treatment allocation was random, where a one-way factorial design was adopted.

4.2.4 Measurements

4.2.4.1 Water intake

Average daily water intake (ADWI) was determined by weighing the water refused every day at 0800 h. For goats subjected to 0 h of water deprivation, the ADWI was determined by subtracting water refused in buckets from that offered to the goats, divided by seven over four weeks. For goats subjected to 24 and 48 h of water deprivation, the ADWI was determined by subtracting water refused in buckets from that offered to the goats, divided by the number of days collected, over four weeks. To cater for water losses, two buckets were placed closer to the pens to estimate the rate of evaporation (Alamer, 2006).

4.2.4.2 Feed intake

Feed intake was determined by weighing the feed contained in feed troughs, including feed refusals every day at 0800 h. Amounts of feed disappeared were considered to be feed ingested by the does. Sacs were placed under all troughs to collect feed spillages. The spillages were dried, weighed and discarded. Weights of feed refusals and spillages were subtracted from the total weight of the feed allocated to each doe and divided by 7 to determine average daily feed intake (ADFI) (Mahgoub *et al*., 2000).

4.2.4.3 Water to feed ratio

The water to feed ratio (WFR) was calculated as the proportion of water to feed consumed daily during the experimental period (Chikumba and Chimonyo, 2014).

4.2.4.4 Average daily gain

Average daily gain (ADG) was measured by weighing the does every week across the whole experiment. The difference in weight of does at the beginning and end of each week divided by 7 determined the ADG (Dzakuma *et al*., 2004). To determine body weight gain (BWG), the does

Table 4.1: Chemical composition of *Medicago sativa* hay, as fed bases

Parameter (g/kg DM except where stated)	Value
Dry matter (g/kg)	811
Gross energy (MJ/kg DM)	17.7
Ash	86.6
Crude protein	189
Ether extracts	12.2
Crude fibre	287
Neutral detergent	398
Acid detergent fibre	386

were weighed weekly, over 4 weeks using RUUDWEIGH, KM-2E electronic weighing system with 0.05 precision (RUUDSCALE, Durbanville, South Africa) (Akingbade *et al*., 2001).

4.2.4.5 Feed conversion ratio

Feed conversion ratio (FCR) was expressed as feed consumed relative to body weight gain (Dzakuma, 2004; Chikumba and Chimonyo, 2014).

4.2.5 Statistical analyses

All data were analysed using the PROC MIXED procedure of SAS (2010). Differences between least square means were tested using the PDIFF option of SAS (2010). A Pearson's correlation test was run to cater for the relationships that exist amongst water and feed intake, including growth performance parameters together with water deprivation.

4.3. Results

4.1 Water and feed intake

The influence of water deprivation × week of successive feeding interaction on ADWI, ADFI and WFR are shown in Table 4.2. In general, the ADWI was largest in goats deprived of water for 48 h compared to those deprived of water for 24 h and 0 h (P <0.05; Table 4.2). The ADWI was similar amongst goats deprived of water for 0 h and 24 h (P <0.05). The ADWI was similar between goats deprived of water for 0 and 24 h compared to those deprived of water for 48 h, with the exception of week three of the feeding period (P <0.05; Table 4.2). The ADFI was largest for goats deprived of water for 48 h compared to those deprived of water for 24 h and 0 h in week 1 and week 4 of the feeding period (P <0.01; Table 4.2). Whereas in week 2 and week 3 of the feeding period, ADFI was smallest for goats deprived of water for 0 h compared to those deprived of water for 24 h and 48 h (P <0.01; Table 4.2). In week 1 of the feeding period, WFR was smallest for goats deprived of water for 48 h compared to those deprived of water for 24 h and 0 h (P <0.01). In week 2 of the feeding period, WFR was largest for goats deprived of water for 48 h and 24 h compared to those deprived of water for 0 h (P <0.01; Table 4.2). Whereas in week 3 and 4 of the feeding period, WFR was similar across all water deprivation periods tested (P >0.05; Table 4.2).

4.2 Growth performance

The effects of water deprivation on ADG and FCR are illustrated in Figure 4.1. Both average daily gain and feed conversion ratio decreased continuously as the period of water deprivation was increased. The correlation coefficients are shown in Table 4.3. Water deprivation period had negative correlations amongst all parameters tested, where ADFI and WFR were weak correlations, with ADG and FCR being moderate correlations. The relationship between water deprivation and ADWI was not significant (P >0.05; Table 4.3).

4.4 Discussion

Observations that goats deprived of water for 48 hours consumed more water compared to those deprived of water for 24 and zero hours was expected. This is because; increased water deprivation causes excessive thirst (Maltz *et al*., 1984; Adogla-Bessa and Aganga, 2000; Prasetiyono *et al*., 2000), such that water consumption increases when goats are rehydrated. Since goats become thirsty due to water deprivation, the bulk of the water offered for rehydration

Table 4.2: Least square means (±SEM) for average daily water intake and average daily feed intake from Nguni goats subjected to varying periods of water deprivation over a 4 week period of successive feeding

Average daily water intake (mL/day)	Week	Water deprivation (h)			SEM
		0	24	48	
	1	1790^a	1800^a	1880^b	39.7
	2	1700^a	1680^a	1800^b	39.7
	3	1730^a	1810^b	1870^c	39.7
	4	1870^a	1840^a	1910^b	39.7
Average daily feed intake (g DM/day)					
	1	485^a	530^b	644^c	37.0
	2	356^a	564^b	596^b	37.0
	3	760^a	826^b	829^b	37.0
	4	269^a	251^a	336^b	37.0
Water to feed ratio (g/mL)					
	1	0.36^c	0.30^b	0.26^a	0.02
	2	0.21^a	0.33^b	0.33^b	0.02
	3	0.44	0.46	0.45	0.02
	4	0.15^a	0.14^a	0.18^b	0.02

^{a,b,c} Within a row, values with the different superscripts differ (P <0.01)

Week: Weeks of successive feeding

is said to largely be consumed in the first 15 minutes of the rehydration period. Under such conditions, goats tend to consume water such that their rumen deficit may be reached to counteract weight loss (Silanikove, 2000; Alamer, 2006). The increased water consumption that results due to water deprivation can be due to that, during rehydration goats consume more water to help regain body weight (Alamer, 2006). As a result, the increased duration of water deprivation in the current study proved to increase water intake. In addition; goats deprived of water result to a reduced metabolism which are counteracted during rehydration (Adogla-Bessa and Aganga, 2000; Silanikove, 2000). For example, Alamer (2006) reported that goats subjected to three days of water deprivation lost a maximum of 21 % of their body weight. At the same time, goats tended to regain weight lost during water rehydration because of an improvement in water and feed intake brought about by excessive thirst.

Water intake is said to be positively related to feed intake (Prasetiyono *et al*., 2000; Muna and Ammar, 2001), the more water goats consume due to thirst the more feed they may consume. This is because water is a medium needed to ensure metabolic processes such as fermentation and degradation that help in the utilization of feed to fulfil goat's nutrient requirements. Observations that goats subjected to water deprivation for 24 and 48 hours consumed more feed compared to those subjected to water deprivation for zero hours were expected. Previous studies have also shown that goats subjected to water deprivation for 24 and 48 hours consume feed in comparable amounts, such that variations in feed intake can be observed when water deprivation period is increased to 72 hours (Adogla-Bessa and Aganga, 2000; Alamer, 2006). This is because; goats conserve water in the rumen to ensure continued potential of a goat to maximize feed resources during times when water is scarce. The storage of water in the rumen by goats is

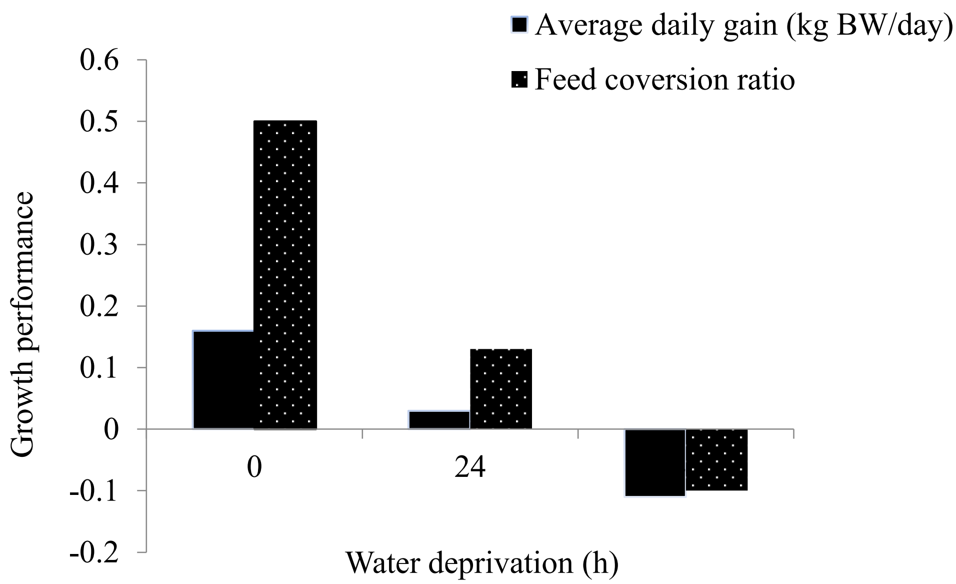


Figure 4.1: Effect of water deprivation period on average daily gain and feed conversion ratio from Nguni goats

Table 4.3: Pearson's correlation coefficients among intake and growth performance parameters of Nguni goats subjected to water deprivation

Parameter	ADWI	ADFI	WFR	ADG	FCR
Deprivation	NS	-0.18*	-0.18*	-0.38**	-0.37**
ADWI		NS	-0.30**	NS	NS
ADFI			0.97**	NS	0.25**
WFR				NS	0.22**
ADG					0.39**

Significance level: ** *P* <0.01; * *P* <0.05; NS not significant (*P* >0.05)

Abbreviations: ADWI: average daily water intake, ADFI: average daily feed intake, WFR: water to feed ratio, ADG: average daily gain, FCR: feed conversion ratio due to that, goats need fluid to ensure secretion of saliva during feeding (Prasetiyono *et al*., 2000). By so doing, the rumen ensures efficient utilization of water. Water medium is needed to ensure softening of feed including the biochemical digestion of feed, at the same time ensuring efficient facilitation of fermentation and digestion processes (Adogla-Bessa and Aganga, 2000). This means, goats do not necessarily need to compensate for feed resources when goats are deprived of water for 48 hours. Reason being, the drive for water consumption is largely brought about by excessive thirst, unless saliva secretion rates are decreased when water reserves have been exhausted (Adogla-Bessa and Aganga, 2000; Prasetiyono *et al*., 2000). This is vital to consider since goats rely on available input resources such as water and feed that are largely limiting in dry seasons (Silanikove, 2000; Rumosa Gwaze *et al*., 2009).

Observations that goats subjected to water deprivation for 48 hours had the smallest average daily gain compared to those subjected to water deprivation for 24 and zero hours are in agreement with results by Adogla-Bessa and Aganga (2000). Although the goats consume more water and feed when subjected to water deprivation for 48 hours, small average daily gain can be related to use of water reserves such that saliva secretion is constrained. By so doing, the goats tend to compensate for losses when resources are availed, resulting in more consumption of water as means of compensating for water reserves in the rumen. Such losses can be linked with reduced feed intake that is influenced by water intake. The regain of body weight following rehydration is due to rapid water storage in extracellular spaces in the rumen, as this helps to keep the goats retaining sufficient need to facilitate metabolic processes. For example, Muna and Ammar (2001) found negative growth from goats subjected to limited water resources, where the growth of goats was associated with water availability rather than feed. Alamer (2006) also found negative growth from goats subjected to water deprivation for three days had lost about 21 % of their body weight. This is because; water availability induces usage of feed resources since water is a medium for metabolic processes needed to fulfil the animal daily requirements. This helps to improve efficiency in the utilization of feed resources in poorly nourished goats (Misra and Singh, 2002), considering that goats rely on communally available input resources which are largely poor to ensure productivity. At the same time, the inconsistent availability of water resources limits fermentation and the digestive processes that help to improve protein gain in goats (Adogla-Bessa and Aganga, 2000; Muna and Ammar, 2001). Hence, in the current study average daily gain was largest for goats subjected to water deprivation for zero hours compared to those subjected to water deprivation for 24 or 48 hours.

On the other hand, the reduced feed conversion efficiency that resulted in the current study as water deprivation was increased can be linked with the ability of goats to utilize limited resources. Adogla-Bessa and Aganga (2000) found an increase in feed conversion efficiency as Tswana goats were subjected to extended periods of water deprivation for two and three days compared to when the goats were subjected to zero and one day of water deprivation. This could be due to that, the Tswana goats were able to efficiently utilize water reserves since water plays an important part in feed utilization in goats. Such a mechanism is a good indicator of the adaptability of a breed to limited water resources. Another factor that could come into play is that, Tswana goats are large framed compared to Nguni goats. For example, Rumosa Gwaze *et al*. (2009) characterized common goats kept under communal production systems of the Southern African region. Nguni does were reported to have a mature weight of 30 kg, whereas Tswana does were reported to have a mature weight of 40 kg. Such variation may influence the capacity of the rumen with regards to the storage of water resources such that the potential of a Tswana goat to store water can be linked to the large frame. As a result, goats with natural larger frame size may have greater potential with withstanding water deprivation; hence goats in the current study resulted to small feed efficiency compared to those studied by Adogla-Bessa and Aganga (2000). This is because; losses of body weight are due to loss of body water when goats are subjected to water deprivation (Alamer, 2006).

4.5. Conclusions

It was concluded that water deprivation influence intake and growth performances, thereby impacting on the productivity of Nguni goats. In general, goats deprived water over 48 hours resulted in largest daily water and feed intakes, although growth did not really prove large intakes result to improved growth amongst goats. Goats deprived of water for 48 hours consumed more water relative to feed compared to those subjected to 24 hours of water deprivation. Average daily gain and feed conversion ratio declined more as the water deprivation period was increased. To ensure efficient use of water resources, one can deprive Nguni goats for 24 h considering that goats subjected to 48 hours of water deprivation resulted in negative growth. Further studies can be done to monitor growth performances from various other common goat breeds of southern Africa that are subjected to water deprivation.

4.6 References

Adogla-Bessa, T. and Aganga, A.A., 2000. Responses of Tswana goats to various lengths of water deprivation, South African Journal of Animal Science, 30(1): 87-91.

Akingbade, A.A., Nsahlai, I.V. and Morris, C.D., 2004. Reproductive performance, colostrum and milk constituents of mimosine-adapted South African Nguni goats on *Leucaena leucocephala*-grass or natural pastures, Small Ruminant Research 52: 253–260.

Akingbade, A.A., Nsahlai, I.V., Bonsi, M.L.K, Morris, C.D. and du Toit, L.P., 2001. Reproductive performance of South African indigenous goats inoculated with DHP-degrading rumen bacteria and maintained on *Leucaena leucocephala*-grass mixture and natural pasture, Small Ruminant Research, 39: 73-85.

Alamer, M., 2006. Physiological responses of Saudi Arabia indigenous goats to water deprivation, Small Ruminant Research, 63: 100–109.

Alamer, M., 2009. Effect of water restriction on lactation performance of Aardi goats under heat stress conditions, Small Ruminant Research 84: 76–81.

Chikumba, N. and Chimonyo, M., 2014. Effects of Water Restriction on the Growth Performance, Carcass Characteristics and Organ Weights of Naked Neck and Ovambo Chickens of Southern Africa, Asian-Australasian Journal of Animal Science, 27(7): 974-980.

Dzakuma, J.M., Risch, E., Smith, C.O. and Blackburn, H.D., 2004. Level of feed intake on performance of two goat genotypes, South African Journal of Animal Science, 34(1): 38-41.

Lehloenya, K.C., Greyling, J.P.C. and Schwalbach, L.M.J., 2005. Reproductive performance of South African indigenous goats following oestrous synchronization and AI, Small Ruminant Research, 57: 115–120.

Mahgoub, O., Lu, C.D. and Early, R.J., 2000. Effects of dietary energy density on feed intake, body weight gain and carcass chemical composition of Omani growing lambs, Small Ruminant Research 37: 35-42.

Maltz, E., Olsson, K., Glick, S.M., Fyhrquist, F., Silanikove, N., Chosniak, I. and Shkolnik, A., 1984. Homeostatic response to water deprivation or haemorrhage in lactating and non lacating Bedouin goats, Comparative Biochemistry and Physiology, 77: 79–84.

Masikati, P., 2010. Improving the water productivity of integrated crop-livestock systems in the semi-arid tropics of Zimbabwe: an ex-ante analysis using simulation modelling. Retrieved January 17, 2012, from http://www.zef.de/fileadmin/webfiles/downloads/zefc_ecology_development/eds_78_masikati_text.pdf.

Misra, A.K. and Singh, K., 2002. Effect of water deprivation on dry matter intake, nutrient utilization and metabolic water production in goats under semi-arid zone of India, Small Ruminant Research, 46: 159–165.

Muna, M.M.A. and Ammar, I.E., 2001. Effects of water and feed restriction on body weight change and nitrogen balance in desert goats fed high and low quality forages, Small Ruminant Research, 41: 19–27.

Pirisi, A., Lauret, A. and Dubeuf, J.P., 2006. Basic and incentive payments for goat and sheep milk in relation to quality, Small Ruminant Research, 68(1–2), 167–178.

Prasetiyono, B.W.H.E., Sunagawa, K., Shinjo, A. and Shiroma, S., 2000. Physiological relationship between thirst level and feed intake in goats fed on alfalfa hay cubes, Asian-Australasian Journal of Animal Sciences, 13(11): 1536-1541.

Rumosa Gwaze, F., Chimonyo, M. and Dzama, K., 2009. Communal goat production in Southern Africa: A review, Tropical Animal Health and Production, 41: 1157–1168.

SAS, 2010. SAS/STAT Software Release 9.3. SAS Institute Inc., Cary, North Carolina, USA.

Silanikove, M., 2000. The physiological basis of adaptation in goats to harsh environments, Small Ruminant Research, 35(3): 181–193.

Tshabalala, P.A., Strydom, P.E., Webb, E.C. and de Kock, H.L., 2003. Meat quality of designated South African indigenous goat and sheep breeds, Meat Science 65: 563–570.

Xazela, N.M., Chimonyo, M., Muchenje, V. and Marume, U., 2012. Effect of sunflower cake supplementation on meat quality of indigenous goat genotypes of South Africa, Meat Science, 90: 204–208.

CHAPTER 5: Influence of water restriction and water salinity on feed intake and growth performance of Nguni does

(This manuscript has been accepted in Small Ruminant Research)

Abstract

The objective of the study was to determine the influence of varying levels of water restriction and water salinity on feed intake and growth performance of Nguni goats. Thirty six Nguni does (initial weight 18 ± 3.2 kg) were used in the study. The goats were housed in individual cages and subjected to six levels of water restriction (100, 90, 80, 70, 60 and 50 %), including three levels of water salinity (11, 5.5 and 0 g/L), with *ad libitum* access to *Medicago sativa* hay. The average daily feed intake (ADFI), water to feed ratio (WFR), average daily gain (ADG) and feed conversion ratio (FCR) were estimated weekly. All the goats completely consumed the water supplied across the six water restriction levels and the three water salinity levels tested. There was a quadratic increase in the ADFI to its peak at 80 % of water restriction level for goats subjected to 0 and 5.5 g/L of water salinity (P <0.01). There was a quadratic decline in the WFR as the level of water restriction was increased for goats subjected to 0 and 5.5 g/L of water salinity level (P <0.05). There was a quadratic increase in the ADG, peaking at 70 and 80 % of water restriction level for goats subjected to 0 and 11 g/L of water salinity level (P <0.05). Also, there was a linear increase in the ADG, peaking at 80 % of water restriction level for goats subjected to 5.5 g/L of water salinity level (P <0.05). There was a quadratic increase in FCR to its peak at 80 % of water restriction level for goats subjected to 0 g/L of water salinity level (P <0.01). Whereas, there was a quadratic decline in FCR to its lowest values at 70 % of water restriction level for goats subjected to 5.5 g/L of water salinity level (P <0.05). It was concluded

that Nguni goats should be restricted to 80 % of water restriction level and up to 5.5 g/L of water salinity, since further levels do not seem to significantly improve the productivity of Nguni goats.

***Key words*:** goats, restriction, salinity, ADFI, ADG, FCR, water

5.1 Introduction

Drinking water resources for goats are limiting under communal production systems, and barely meet their daily requirements since goats travel long distances to access water points (Misra and Singh, 2002; Masikati, 2010). Where water points are available, water is often of poor quality due to considerable amounts of dissolved solids such as sodium and chloride that reduce the quality if drinking water for goats (McGregor, 2004a; Alamer, 2009; Maldonado-Valderrama *et al*., 2011). Low water supply and reduced quality are tangible constraints under communal production systems. Such conditions are stressful, and influence the performance of livestock, since water is directly linked to feed intake. Goats are thought to have developed mechanisms to withstand conditions of water shortages where water resources are poor in quantity and quality (Alamer, 2006). These include minimizing the loss of water stored in the rumen to help maintain feed intake during periods where water resources are poor. Goats tend to minimize water intake to help manage salt levels in the body by excreting increased amounts of sodium and chloride through urinary excretions, as the salinity levels of drinking water is increased (McGregor, 2004b; Yape Kii and Dryden, 2005; Alamer, 2006; Alamer, 2009).

Water challenges are projected to grow due to broader changes caused by climate change and global warming (Arnell, 1999; Mabhaudhi *et al*., 2013; News24, 2014). Such effects result in limited availability of water resources particularly for livestock, such that, water resources tend to decline in quality. This leads to needs for incorporating the concept of water restriction with water salinity using indigenous breeds to water stress. Subjecting Nguni goats to such conditions makes it easy to understand their adaptability so as to help farmers maximize the potential of goats to utilize poor water resources regarding intake and growth. It is of great importance to use does when monitoring the adaptability of goats to poor water resources. This is because; the productivity of goats is determined by females since they produce offsprings that define the gross income from a flock (Akingbade *et al*., 2001). The objective of the current study was to determine the influence of levels of water restriction and water salinity on feed intake and growth performance of Nguni does. The hypothesis tested in the current study was that, varying levels of water restriction and water salinity level influence intake and growth performance of Nguni does.

5.2 Materials and Methods

5.2.1 Study site and ethical consideration

The study site and ethical consideration are described same as 4.2.1.

5.2.2 Goat management, diets and experimental design

A total of 36 Nguni does ranging from 9 to 31.5 kg, averaging (18 ± 3.2 kg) were de-wormed with 2 mL of Zolvix Monepantel® (Novartis Animal Health, Australia) and confined in individual pens. Goats were confined for 38 days. They were subjected six levels of water restriction (50, 60, 70, 80, 90 and 100 %) and three levels of water salinity (0, 5.5 and 11 g/L). These water restriction levels were translated to 1 000, 1 200, 1 400, 1 600, 1 800 and 2 000 mL of water per day. Ajibola (2000) reported indigenous goats consume about 1.47 litres of water per day. Therefore, the threshold for *ad libitum* supply of water for the current study was set to 2000 mL of water per goat per day. McGregor (2004a) reported the safe threshold for saline water for use in goats as 11 mg of total dissolved solids per litre. Therefore, the maximum threshold for salt in the current study was set as 11 g/L of salt per litre of water provided to the goats. The water was supplied using 5 litre buckets purchased from TWK Agriculture Ltd (Pietermaritzburg, South Africa). The buckets were fitted in each pen such that the water supplied was accessed by one goat. All the goats finished the water supplied across the six water restriction and the three water salinity levels tested. Goats were fed on *Medicago sativa* hay purchased from TKW Agriculture Ltd (Pietermaritzburg, South Africa). Hay was chopped to pass through a 5 cm screen. Xazela *et al*. (2012) reported that, *Medicago sativa* hay is sufficient to meet the maintenance and growth requirements of goats. Feed was offered *ad libitum*. The chemical composition of the hay is shown in Table 4.1. Treatments were allocated randomly and followed a two-way factorial design (water restriction and water salinity). The experiment was repeated using the same design due to limited number of goats available at the farm to ensure four replicates per treatment.

5.2.4 Measurements

5.2.4.1 Feed intake

Feed intake (FI) was determined was described earlier (Section 4.2.4.2).

5.2.4.2 Water to feed ratio

Water to feed ratio (WFR) was calculated as the proportion of water to feed consumed daily during the experimental period (Chikumba and Chimonyo, 2014). The average daily water consumption was determined by subtracting water refused in buckets from that offered to the goats divided by seven, over four weeks. To cater for water losses, two buckets were placed closer to the pens to estimate the rate of evaporation (Alamer, 2006).

5.2.4.3 Average daily gain

The estimation of average daily gain (ADG) was as described in section 4.2.4.4.

5.2.4.4 Feed conversion ratio

The calculation of feed conversion ratio (FCR) was as described in section 4.2.4.5.

5.2.5 Statistical analyses

The PROC MIXED procedure of SAS (2010) for repeated measures was used to test for significance of water restriction level and water salinity level on intake (ADFI and WFR) and growth performance (ADG and FCR). First-order autoregressive correlation (AR (1)) was fitted to the model. Differences between least square means were tested using the PDIFF option of SAS (2010). The following model was used:

$Y_{ijk} = \mu + R_i + S_j + W_k + (R \times S \times W)_{ijk} + E_{ijk}$, where:

Y_{ijk} - was the response variable

μ - was the overall mean common to all observations

R_i - was the effect of water restriction level

S_j - was the effect of water salinity level

W_k – was the effect of week of successive feeding

$(R \times S \times W)_{ijk}$ - was the interaction between water restriction level, water salinity level and week of successive feeding

E_{ijk}- was the residual error

The PROC REG of SAS (2010) was used to determine the relationships between water restriction level together with water salinity level on intake (ADFI and WFR), including growth performance (ADG and FCR).

5.3 Results

5.3.1 Feed intake

Relationships between ADFI and WFR with water restriction level together with water salinity level are shown in Table 5.1. There was a quadratic relationship between the ADFI and water restriction level for goats subjected to 0 and 5.5 g/L of water salinity level (P <0.01; Table 5.1). The ADFI increased to its peak, and later declined beyond 80 % of water restriction level for goats subjected to 0 and 5.5 g/L of water salinity level (Figure 5.1). There was a quadratic relationship between WFR and water restriction level for goats subjected to 0 and 5.5 g/L of water salinity level (P <0.05; Table 5.1). The WFR declined as the level of water restriction decreased for both 0 and 5.5 level of water salinity (Figure 5.1).

5.3.2 Growth performance

Relationships between ADG and FCR with water restriction level together with water salinity level are shown in Table 5.2. There was a quadratic relationship between the ADG and water

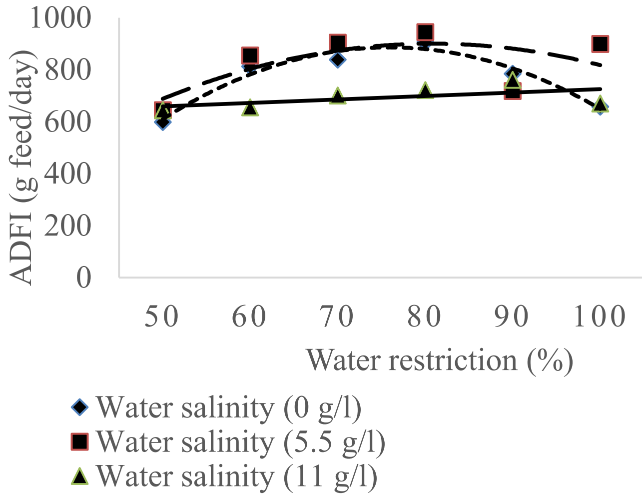
Table 5.1: Relationships between water restriction and water salinity on ADFI and WFR

Parameter	Water salinity	Water restriction (%)						SEM	Regression coefficient		R-square	Sig
	(g/L)	50	60	70	80	90	100		Linear	Quadratic		
ADFI	0	598	813	838	906	784	657		62.23	-0.409	0.95	**
(g feed/day)	5.5	644	855	904	944	718	898	44.1	36.15	-0.224	0.43	**
	11	643	655	701	721	761	669					NS
WFR	0	0.60	0.68	0.60	0.57	0.44	0.33		0.024	-0.0002	0.79	*
	5.5	0.64	0.71	0.65	0. 59	0.40	0.45	0.030		-0.0001	0.89	*
	11	0.64	0.55	0.50	0.45	0.42	0.34					NS

** (P <0.01); * (P <0.05); NS Not significant

Abbreviations: ADFI: average daily feed intake, WFR: water to feed ratio, SEM: standard error of mean

Sig: significance



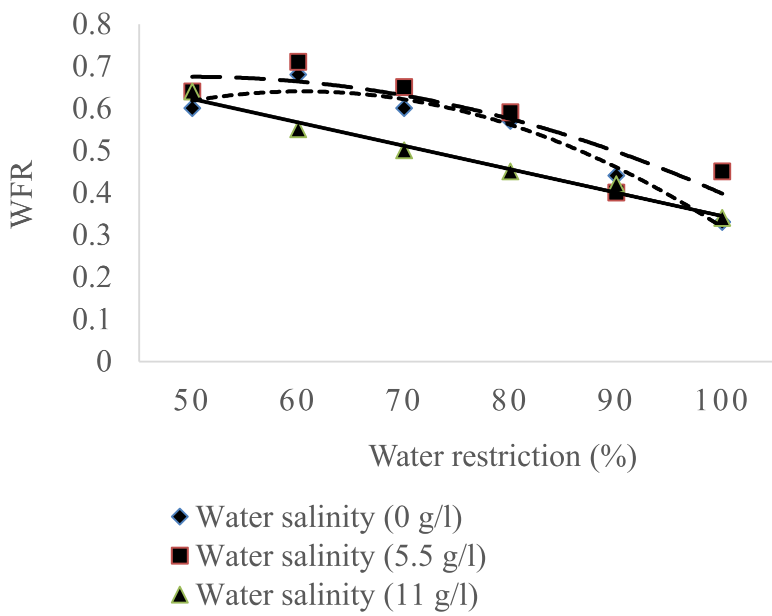


Figure 5.1: Influence of water restriction and water salinity on average daily feed intake (ADFI) and water to feed ratio (WFR) in Nguni does

Table 5.2: Effect of water restriction and water salinity on ADG and FCR

Parameter	Water salinity (g/L)	Water restriction (%)						SEM	Regression coefficient		R-square	Sig
		50	60	70	80	90	100		Linear	Quadratic		
ADG	0	0.06	0.07	0.07	0.08	0.07	0.07		0.027	-0.0002	0.7938	*
(kg BW/day)	5.5	0.08	0.08	0.09	0.10	0.09	0.09	0.006	0.021		0.1325	*
	11	0.07	0.08	0.09	0.08	0.08	0.07		0.030	-0.0002	0.7326	*
FCR	0	0.029	0.046	0.044	0.050	0.042	0.030		0.005	-0.00003	0.9023	**
	5.5	0.038	0.040	0.026	0.035	0.032	0.038	0.004	-0.002	0.00001	0.3913	*
	11	0.035	0.034	0.028	0.034	0.037	0.036					NS

** (P <0.01); * (P <0.05); NS Not significant

Abbreviations: ADG: average daily gain, FCR: feed conversion ratio, SEM: standard error of mean

Sig: significance

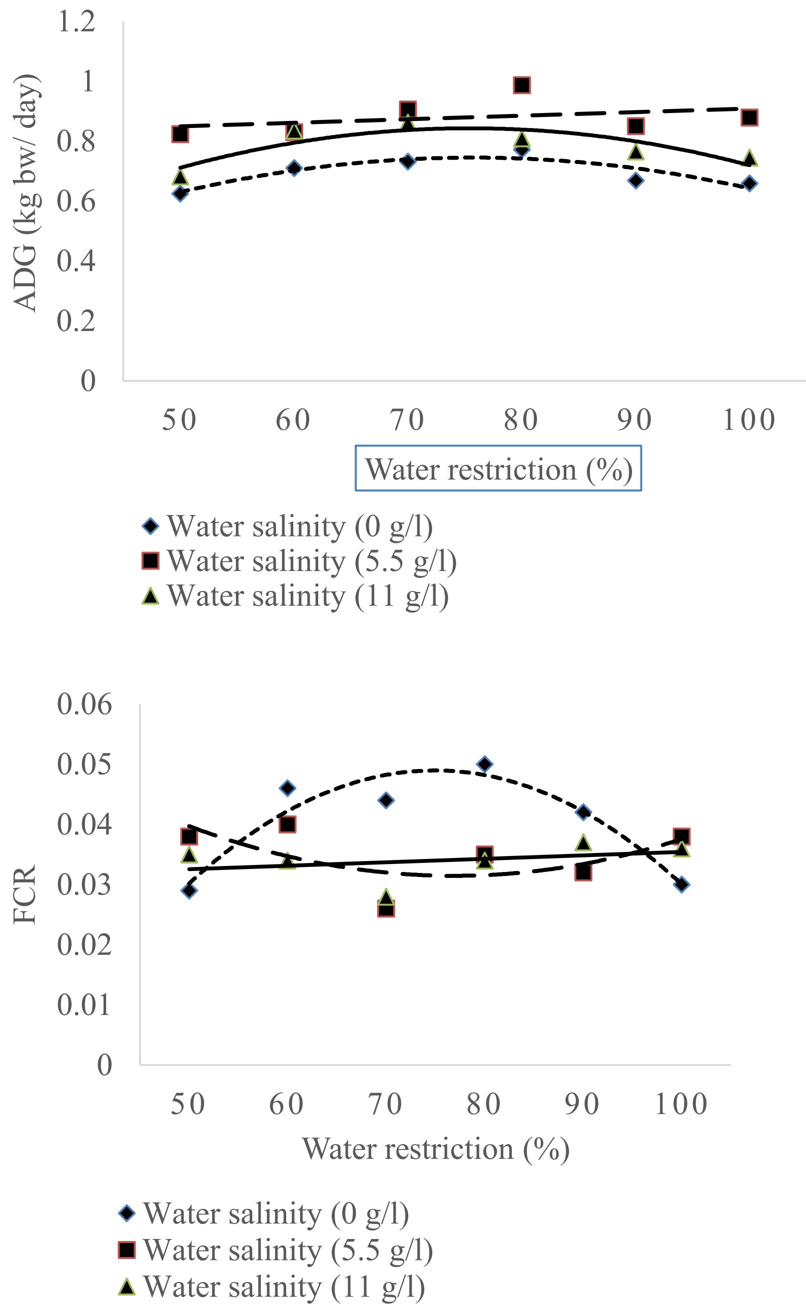


Figure 5.2: Influence of water restriction and water salinity on average daily gain (ADG) and feed conversion ratio (FCR) in Nguni does

restriction level for 0 and 11 g/L of water salinity level ($P < 0.01$; Table 5.2). The ADG peaked at 70 and 80 % of water restriction level for goats subjected to 0 and 11 g/L of water salinity level (Figure 5.2). Also, there was a linear relationship between ADG and water restriction level for goats subjected to 5.5 g/L of water salinity level ($P < 0.05$; Table 5.2). The ADG increased as the level of water restriction was increased and peaked at 80 % for goats subjected to 5.5 g/L of water salinity level (Figure 5.2). There was a quadratic relationship between FCR and water restriction level for goats subjected to 0 and 5.5 g/L of water salinity level ($P < 0.01$; Table 5.2) and ($P < 0.05$; Table 5.2), respectively. The FCR peaked at 80 % of water restriction level for goats subjected to 0 g/L of water salinity level (Figure 5.2). However, the FCR declined furthest at 70 % of water restriction level for goats subjected to 5.5 g/L of water salinity level.

5.4 Discussion

The observation that goats consumed more water as water restriction level decreased was expected. Results from the current study agree with Muna and Ammar (2001) who reported a decrease in feed intake as the water restriction level was increased in Sudanese desert goats fed Lucerne hay and Sorghum hay. Water intake is directly related to feed intake such that increased water intake encourages goats to consume more feed (Prasetiyono *et al*., 2000; Muna and Ammar, 2001). Water is needed to facilitate metabolic processes required to catalyse the feed in ruminants, also to provide a sound environment for microbes in the rumen. However, the decline in feed intake as water restriction level decreased beyond 80 % could be justified by that, goats reached nutrient satiety at 80 % water restriction level. It is also vital to recall that, goats tend to consume more water not necessarily to satisfy their daily water requirements, but to counteract excessive thirst brought about by excessive drinking behaviours (Adogla-Bessa and Aganga, 2000; Prasetiyono *et al*., 2000). At the same time, McGregor (2004b) found no difference in feed intake when sheep and goats were subjected to clean water and saline water of up to 9.5 g/L of total dissolved solids. However, an increase in water salinity level in the current study caused a decline in feed intake. Feed consumed was the largest when Nguni goats were subjected to 0 and 5.5 g/L of water salinity level compared to those subjected to 11 g/L of water salinity level. Such evidence confirms the fact that water intake is directly related to feed intake McGregor (2004b), since goats subjected to 11 g/L of water salinity level resulted in small feed intake.

Findings that water to feed ratio declined as water restriction level was decreased were expected. Findings from the current experiment disagree with Abioja *et al*. (2010) who reported the ratio of water to feed to have declined when the West African Dwarf and Red Sokoto goats were subjected to increased levels of water restriction. Goats voluntarily reduce water intake when water resources become limited. By so doing, goats tend to efficiently utilize the fewest available water resources to ensure uptake of sufficient feed per unit of water available. This is because, goats apply water-saving mechanisms when water resources are in short supply (Adogla-Bessa and Aganga, 2000; Alamer, 2009; Abioja *et al*., 2010). On the other hand, the WFR was generally smallest at 11 g/L of water salinity level. Results from the current experiment contradict with Yape Kii and Dryden (2005). When water resources are more saline, goats tend to reduce their drinking habits, resulting in loss of water through urine as goats keep eliminating sodium in the body (Yape Kii and Dryden, 2005). Therefore, goats utilize feed resources efficiently since provision of sufficient water resources of good quality is not guaranteed for goats. By so doing, goats display desirable indications of efficient budgeting of water resources.

The observation that average daily gain tended to increase as water restriction level was decreased, including its later decrease can be associated with the trend in which the goats responded to regarding feed intake. In agreement, Abioja *et al*. (2010) reported negative growth when West African Dwarf and Red Sokoto goats were subjected to increased water restriction levels. Reports that goats grow as water supply is increased are in agreement with results from the current study. Reducing water restriction level has been reported to favour feed intake in goats (Prasetiyono *et al*., 2000; Muna and Ammar, 2001), tending to help accelerate growth. However, findings from the current study show a negative growth for goats subjected to water restriction levels beyond 80 %. This response could be due to that, feed intake tended to decrease at the same level, including the potential of conversion of feed to muscle. This is because less feed consumed tends to reduce average daily gain when animals are subjected to increased levels of water restriction (Abioja *et al*., 2010; Chikumba and Chimonyo, 2014). On another note, increased average daily gain as water salinity levels increased can be related to that, total dissolved solids such as sodium and chloride are essential in the absorption of several nutrients such as glucose and some amino acids in the small intestines (Maldonado-Valderrama *et al*., 2011). Providing animals with adequate salt is, therefore, critical for maximizing utilization of energy, protein, and some minerals. It has been reported that, water restriction level and water salinity level have an impact on growth since sufficient water resources of good quality encourage maximum utilization of available feedstuffs by goats (Casamassima *et al*., 2008). Therefore, the adaptability of the Nguni goat to saline water is understood since goats resisted salt toxicity considering that growth was maximised at the highest levels of water salinity tested in the current experiment.

Findings that goats resulted in the largest feed conversion ratio at 80 % of water restriction level when subjected to 0 g/L of water salinity level can be related to that, maximum feed intake together with weight gain were largest at the same threshold. Abioja *et al*. (2010) reported largest feed conversion ratio when the West African Dwarf and Red Sokoto goats were subjected to the lowest levels of water restriction. Such results contradict with the current study since goats subjected to 50 % of water restriction level and that of the control resulted to a smaller feed conversion ratio. This means goats can efficiently utilize water resources available in small amounts, making them suitable for areas that are drought stricken. At the same time, goats efficiently utilize water resources when water is largely available. This means goats easily adapt to various conditions pertaining water availability brought about by the water-saving mechanisms that goats poses in the rumen to help regulate metabolic water (Adogla-Bessa and Aganga, 2000; Alamer, 2009; Abioja *et al*., 2010). At the same time, the small feed conversion ratio that resulted as water salinity level was increased can be related to the ability of goats to utilize small amounts of water and feed resources to yield muscle. This can be due to that salt in water encourage the absorption of nutrients in the small intestines (Maldonado-Valderrama *et al*., 2011). These include amino acids which contribute to the development of muscle, desirable for growth. Such response indicates a good adaptability of the Nguni goat to poor water resources.

5.5 Conclusions

In conclusion, goats consume more water as water restriction levels are decreased across all water salinity levels tested. This can be related to the needs for ensuring maintenance of sufficient water in the rumen to help in the utilization of feed resources. Feed intake, average daily gain and water to feed ratio were largest at 80 % of water restriction level for 0 and 5.5 g/L of water salinity level, indicating that more water consumed was not necessarily used to ensure growth but to satisfy thirst brought about by water deficit. Threshold pertaining water restriction for Nguni goats can be set to 80 % of water restriction level since further levels of water restriction do not seem to improve feed intake and growth performance. On the other hand, goats consumed less water when water salinity level was increased to 11 g/L. Goats tend to lose water in the process of decreasing salts through urine, resulting in small intake hence feed intake including water to feed ratio were smallest at 11 g/L of water salinity level. This means goats can tolerate the highest levels of water salinity level tested in the current study, indicating good adaptive characteristics of the Nguni goat breed to poor water resources.

5.6 References

Abioja, M.O., Osinowo, O.A., Adebambo, O.A., Bello, N.J. and Abiona, J.A., 2010. Water restriction in goats during hot-dry season in the humid tropic: feed intake and weight gain, Archivos de Zootecnia, 59: 195–203.

Adogla-Bessa, T. and Aganga, A.A., 2000. Responses of Tswana goats to various lengths of water deprivation, South African Journal of Animal Sciences, 30(1): 87-91.

Ajibola, A., 2000. The effect of water deprivation and atropine administration on gastro-intestinal function in goats, MSc (Dissertation), University of Pretoria, Pretoria, South Africa.

Akingbade, A.A., Nsahlai, I.V., Bonsi, M.L.K., Morris, C.D. and du Toit, L.P., 2001. Reproductive performance of South African indigenous goats inoculated with DHP-degrading rumen bacteria and maintained on Leucaena leucocephala/grass mixture and natural pasture, Small Ruminant Research, 39(1): 73–85.

Alamer, M., 2006. Physiological responses of Saudi Arabia indigenous goats to water deprivation, Small Ruminant Research, 63: 100–109.

Alamer, M., 2009. Effect of water restriction on lactation performance of Aardi goats under heat stress conditions, Small Ruminant Research, 84: 76–81.

Arnell, N.W., 1999. Climate change and global water resources. Global Environmental Change, 9: S31–S49.

Casamassima, D., Pizzo, R., Palazzo, M., D'Alessandro, A.G. and Martemucci, G., 2008. Effect of water restriction on productive performance and blood parameters in comisana sheep reared under intensive condition, Small Ruminant Research, 78: 169–175.

Chikumba, N. and Chimonyo, M., 2014. Effects of Water Restriction on the Growth Performance, Carcass Characteristics and Organ Weights of Naked Neck and Ovambo Chickens of Southern Africa, Asian-Australasian Journal of Animal Science, 27(7): 974-980.

Mabhaudhi, T., Modi, A.T. and Beletse, Y.G., 2013. Growth, phenological and yield responses of a Bambara groundnut (*Vigna subterranea* L. Verdc) landrace to imposed water stress: II. Rain shelter conditions, Water South Africa, 39: 191–198.

Maldonado-Valderrama, J., Wilde, P., Macierzanka, A. and Mackie, A., 2011. Advances in Colloid and Interface Science, 165: 36–46.

Masikati, P., 2010. Improving the water productivity of integrated crop-livestock systems in the semi-arid tropics of Zimbabwe: an ex-ante analysis using simulation modelling. Retrieved January 17, 2012, from http://www.zef.de/fileadmin/webfiles/downloads/zefc_ecology_development/eds_78_masikati_text.pdf.

McGregor, 2004a. The use and macro-mineral content of saline water for goat production, South African Journal of Animal Sciences, 34(1): 215-218.

McGregor, B.A., 2004b. Water quality and provision for goats. A report for the Rural Industries Research and Development Corporation. RIRDC Publication No.04/036.Rural Industries Research and Development Corporation, Canberra.

Misra, A.K. and Singh, K., 2002. Effect of water deprivation on dry matter intake, nutrient utilization and metabolic water production in goats under semi-arid zone of India, Small Ruminant Research, 46: 159–165.

Muna, M.M.A. and Ammar, I.E., 2001. Effects of water and feed restriction on body weight change and nitrogen balance in desert goats fed high and low quality forages, Small Ruminant Research, 41: 19–27.

News24, 2014. SA a water-scarce country - Zuma. [Online] Available from: http://www.news24.com/SouthAfrica/News/SA-a-water-scarce-country-Zuma-20141101. [Accessed: 10th November 2015].

Prasetiyono, B.W.H.E., Sunagawa, K., Shinjo, A. and Shiroma, S., 2000. Physiological relationship between thirst level and feed intake in goats fed on alfalfa hay cubes, Asian Australas. Journal of Animal Science, 13(11): 1536-1541.

SAS, 2010. SAS/STAT Software Release 9.3. SAS Institute Inc., Cary, North Carolina, USA.

Xazela, N.M., Chimonyo, M., Muchenje, V. and Marume, U., 2012. Effect of sunflower cake supplementation on meat quality of indigenous goat genotypes of South Africa, Meat Science, 90: 204–208.

Yape Kii, W. and McL. Dryden, G., 2005. Effect of drinking saline water on food and water intake, food digestibility, and nitrogen and mineral balances of rusa deer stags (*Cervus timorensis russa*), Animal Science, 81: 99-105.

CHAPTER 6: Influence of water deprivation period on the nutritional status of Nguni goats

(The paper is under review at Asian-Australasian Journal of Animal Science)

Abstract

The objective of the study was to determine the influence of varying periods of water deprivation (0, 24 and 48 h) on body condition scoring, body weight, faecal egg counts, FAMACHA, and blood metabolites of Nguni goats. A total of 36 Nguni does (initial weight (18±3.2 kg) were used in the study. The goats were housed in individual cages and subjected to varying periods of water deprivation (0, 24 and 48 h), with *ad libitum* access to *Medicago sativa* hay. The body condition scoring (BCS), body weight (BW), faecal egg counts (FEC), including FAMACHA scores were determined weekly. Blood metabolites (glucose, creatine kinase, urea kinase and cholesterol) were determined on the last day of the experiment. Body condition scoring and body weight were largest for goats deprived of water for 0 h (P <0.01). The FEC increased as water deprivation period was increased. FAMACHA scores were highest for goats deprived of water for 0 and 24 h (P <0.01). Serum glucose and cholesterol were largest for goats deprived of water for 24 and 48 h (P <0.01) and (P <0.05), respectively. Creatine kinase was largest for goats deprived of water for 48 h (P <0.01). Correlations for water deprivation period were negative with FAMACHA, BCS and BW and positive with FEC and creatine kinase. The BCS had a positive correlation with BW. The BW had negative correlations with FEC, whereas positive with serum glucose. It was concluded that BCS, BW and FAMACHA declined as the water deprivation period was increased, whereas FEC and blood metabolites declined as the water deprivation was decreased.

***Keywords*:** Deprivation, Nguni goats, water resources, blood metabolites

6.1 Introduction

In sub-Saharan Africa, goats are largely kept by resource-poor farmers. The majority of goats are indigenous genotypes kept under communal production systems (Rumosa Gwaze *et al*., 2009). In South Africa, the most popular goat breed is the Nguni found across communal production systems, characterised by lack of input resources such as water necessary to help goats meet their daily nutritional requirements (Abioja *et al*., 2014). As such, goats have to walk long distances in search to source water resources, away from grazing areas. In Zimbabwe, goats sometimes walk for about 14 km in search for drinking water. Such circumstances lead to goats facing periods of water deprivation since water resources are scarce (Masikati, 2010). Such conditions are stressful and significantly impact on the performance of indigenous goats. However, indigenous goat breeds have been reported to be able to withstand harsh conditions such as water deficit (Adogla-Bessa, and Aganga, 2000; Alamer, 2006; Casamassima *et al*., 2008). One of those is water deprivation which is necessary to understand its impact on the nutritional status and well-being of goats kept under harsh conditions.

Various methods have been used to evaluate the nutritional status of goats. These include; body condition scoring, body weight, FAMACHA, faecal egg counts, including blood metabolites such as glucose, creatine and urea kinase, and cholesterol. Monitoring the nutritional status for livestock using body condition scoring and body weight, including worm infestation have widely been employed (Ndlovu *et al*., 2007; Rumosa Gwaze *et al*., 2010a). Such measures have been reported as inaccurate if they do not consider blood metabolites such as glucose, creatine and urea kinase and cholesterol (Rumosa Gwaze *et al*., 2010b). However, such developments did not consider stress effects such as water unavailability that goats are prone to under communal production systems, especially during dry seasons.

Therefore, there is a need to subject goats to various levels of water deprivation to monitor the nutritional status of Nguni goats since they are the most abundant goat breeds in South Africa. Subjecting Nguni goats to water deprivation is necessary to understand the adaptability of goats subjected to limited input resources since goats survive periods of water unavailability. By so doing, it can be easy to understand water deprivation thresholds that goats can withstand at the same time maintaining good nutritional and health standards for goats kept under sub-tropical regions. The objective of the current study was, therefore, to determine the influence of varying water deprivation periods on body condition scoring, body weight, faecal egg counts, FAMACHA scores and blood metabolites of Nguni goats. It was hypothesised that, varying water deprivation periods will affect the nutritional status of Nguni goats.

6.2 Materials and Methods

6.2.1 Study site and ethical consideration

The study site and ethical considerations are described in Section 4.2.1.

6.4.2 Goat management, feeding and experimental design

Goat management, feeding and the experimental design are as described in section 4.2.2.

6.2.3 Blood collection

Blood samples were collected by jugular venepuncture into evacuated collection tubes containing Li heparin (Terumo Europe NV Leuven, Belgium), on the last day of the experiment. Blood samples were collected into tubes on ice using Na-EDTA as anti-coagulant. All tubes were placed immediately on ice, and then transferred to the laboratory, where plasma was aspirated within two hours of collection following centrifugation at 3000 x g for 10 minutes. After centrifugation, the plasma were stored at −20 °C (Pambu-Gollah *et al*., 2000; Stella *et al*., 2007).

6.2.4 Measurements

6.2.4.1 Body condition scoring

Body condition scoring (BCS) was done using a scale of 1 (emaciated), 2 (thin), 3 (average condition), 4 (fat) and 5 (obese) once a week, over 4 weeks as described by Gerhart *et al*. (1996).

6.2.4.2 Body weight

The does were weighed weekly, over 4 weeks using RUUDWEIGH, KM-2E electronic weighing system with a precision of 0.05 (RUUDSCALE, Durbanville, South Africa) (Akingbade *et al*., 2001).

6.2.4.3 Faecal egg counts

Faecal egg counts were determined using the McMaster technique with a saturated solution of sodium chloride as the flotation medium, as reported by Rumosa Gwaze *et al*. (2010). Four grams of faeces were mixed in 56 mL of saturated solution of sodium chloride. The number of nematode eggs per gram of faeces was obtained by multiplying the total number of eggs counted in the two squares of the McMaster slide by the dilution factor of 50. The McMaster technique detects 50 or more eggs per gram of faeces.

6.2.4.4 FAMACHA scores

The FAMACHA scores were determined by opening the lower eyelid of the goat and comparing the colour of the conjunctivae with five different scores on a chart where score number 1 indicated a non-anaemic goat whilst a 5 indicated a severely anaemic goat according to Kaplan *et al*. (2004). One veterinarian and a farm worker with more than 20 years experience were responsible for eye scoring. The allocation of FAMACHA scores followed description in Table 6.1.

6.2.4.4 Blood metabolites

Plasma glucose and creatine kinase were analysed using commercially available diagnostic kits (Sigma Diagnostics, St. Louis, MO). Blood samples were also analysed for urea (Berthelot method, Reagents Applications Inc., San Diego, California), glucose (glucose oxidase method, Reagents Applications Inc., San Diego, California), and cholesterol (cholesterol esterase method, South African Institute for Medical Research, Sandringham, South Africa) (Pambu-Gollah *et al*., 2000).

Table 6.1: FAMACHA score descriptions used in the current experiment

Score	FAMACHA description
1	Optimal: Red colour non-anaemic
2	Acceptable: Red-pink colour non-anaemic
3	Borderline: Pink mildly anaemic
4	Dangerous: Pink-white anaemic
5	Fatal: Porcelain white severely anaemic

Source: Rumosa Gwaze (2009)

6.2.5 Statistical analyses

Data concerning live weight changes and body condition scoring, including blood metabolites from does were analysed using PROC GLM of SAS (2010). The number of weeks for body condition scoring, live weight, faecal egg counts and FAMACHA were used as covariates. However, the week effect was not used as a covariate for blood metabolites since they were collected on the last day. The differences between least square means were tested using the PDIFF option of (2010). Body condition scores and FAMACHA scores were root transformed whilst faecal egg counts were transformed using $\log_{10}$ (FEC + 1) to normalise the data. The linear model used was described as follows:

$Y_{ij} = \mu + D_i + W_j + E_{ij}$

Where Y_{ij} = response variable for each goat;

μ = overall mean;

D_i = water deprivation (i = 0, 24 and 48 h);

W_j = week of successive feeding (j = week 1, 2, 3 and 4);

The interaction of water deprivation and week of successive feeding was not significant across all parameters tested, therefore, it was removed from the model. PROC CORR of SAS (2010) was used to test for relationships that exist amongst body condition scoring, body weight, faecal egg counts, FAMACHA and blood metabolites tested.

6.3 Results

6.3.1 Summary statistics and levels of significance

Water deprivation period influenced BCS and blood cholesterol (P <0.05). Body weight, FAMACHA, blood glucose and creatine kinase (P <0.01). Week of successive feeding influenced body weight and faecal egg counts (P <0.05).

6.3.2 Body condition scoring, body weight, faecal egg counts and FAMACHA

Body condition scoring and body weight were largest for goats deprived of water for 0 h compared to those deprived of water for 24 and 48 h (P <0.01; Table 6.2). Faecal egg counts increased as the water deprivation period was increased. FAMACHA scores were largest for goats deprived of water for 0 and 24 h compared to those deprived of water for 48 h (P <0.01; Table 6.2).

6.3.3 Blood metabolites

Serum glucose and cholesterol was largest for goats deprived of water for 24 and 48 h compared to those deprived of water for 0 h (P <0.01; Table 6.2) and (P <0.05), respectively. Creatine kinase was largest for goats deprived of water for 48 h compared to those deprived of water for 0 and 24 h (P <0.01; Table 6.2).

6.3.4 Correlations

The correlation coefficients among body condition scoring, body weight, faecal egg counts, FAMACHA, and blood metabolites for Nguni goats subjected to water deprivation are shown on Table 6.3. Correlations for water deprivation period were negative but weak correlation for

Table 6.2: Least square means (±SEM) for body condition scoring, body weight, faecal egg counts, FAMACHA scores and blood metabolites of Nguni goats subjected to varying periods of water deprivation

Parameter	Water deprivation period (hours)		
	0	24	48
Body condition score	3.1 ± 0.08^{b}	2.6 ± 0.08^{a}	2.4 ± 0.08^{a}
Body weight (kg)	22.1 ± 0.7^{c}	17.5 ± 0.7^{b}	14.8 ± 0.7^{a}
Faecal egg count (eggs/g)	2004 ± 341.5^{a}	2375 ± 341.5^{ab}	2996 ± 341.5^{b}
FAMACHA	2.9 ± 0.08^{b}	2.9 ± 0.08^{b}	2.6 ± 0.08^{a}
Blood metabolites			
Glucose (mmol/L)	3.4 ± 0.19^{a}	4.1 ± 0.18^{b}	4.4 ± 0.20^{b}
Creatine (mmol/L)	20.4 ± 2.59^{a}	23.7 ± 2.48^{a}	38.3 ± 2.72^{b}
Urea (mmol/L)	1.2 ± 0.11	1.1 ± 0.11	1.2 ± 0.12
Cholesterol (mmol/L)	2.8 ± 0.48^{a}	4.2 ± 0.46^{b}	5.0 ± 0.50^{b}

^{a,b,c}Within a row, values with the different superscripts differ (P <0.05)

Abbreviations: FEC: faecal egg counts

Table 6.3: Pearson's correlation coefficients among water deprivation period, body condition scoring, body weight, faecal egg counts, FAMACHA, and blood metabolites of Nguni goats

Parameter	BCS	BW	FEC	FAMACHA	Glucose	CK	UK	Cholesterol
Deprive	-0.40**	-0.54**	0.28**	-0.16*	NS	0.15*	NS	NS
BCS		0.15*	NS	NS	NS	NS	NS	NS
BW			-0.25**	NS	0.20*	NS	NS	NS
FEC				NS	-0.18*	NS	NS	NS
FAMACHA					NS	NS	NS	NS
Glucose						0.37**	NS	0.48**
CK							0.22*	0.55**
UK								0.44
Cholesterol								

Significance level: ** P <0.01; * P <0.05; NS not significant (P >0.05)

Abbreviations: Deprive: water deprivation period, BCS: body condition scoring, BW: body weight, FEC: faecal egg counts, CK: creatine kinase, UK: urea kinase

FAMACHA, positive but weak for faecal egg counts and creatine kinase, negative but moderate for body condition scoring and negative but strong for body weight. Body condition scoring had a positive but weak correlation with body weight. Correlations for body weight were negative but weak with faecal egg counts, whereas with serum glucose they were positive but weak. Faecal egg counts had negative but weak correlations with serum glucose.

6.4 Discussion

Findings that goats resulted in small body condition and body weight as the water deprivation period was increased were expected. When water resources are available, goats tend to efficiently utilize feed resources since water is a medium necessary to ensure metabolism, and when water resources are limited, goats tend to lose condition (Sejian *et al*., 2010). When water resources are available following a period of water scarcity, goats tend to maximize water and feed intake to counteract losses in body weight (Adogla-Bessa and Aganga, 2000). At the same time adopting water-saving mechanisms that help avail water resources over the next periods of water deprivation. This is done by minimizing losses of water in the body and saving water in the extracellular spaces in the rumen to partition water towards metabolism needed for daily body maintenance. Findings that body weight declines as goats are subjected to increased periods of water deprivation to be in agreement with finding by Alamer (2006). Such decrease in body weight, similarly to body condition scoring is due to decrease in feed intake including water intake together with loss of body weight which largely occurs during dehydration. It has been reported that water deficit supresses feed intake even if goats are supplied with large amounts of feed (Silanikove, 2000; Ahmed and El-Kheir, 2004). Therefore, it is necessary for goats to efficiently utilize their water-saving mechanism to ensure continued utilization of feed resources even if water resources are limited to ensure continued nourishment. Studies have shown that body condition scoring relates to body weight (Adogla-Bessa and Aganga, 2000; Alamer, 2006; Rumosa Gwaze *et al*., 2010; Sejian *et al*., 2010), and are both due to intake influenced by the availability of water resources. Findings that water deprivation resulted in a decline in body condition scoring and body weight in the current study proved the negative correlation that exists between water deprivation period together with body condition scoring and body weight.

The FAMACHA technique together with faecal egg counts are direct measures to test the resistance of goats to parasite infestations such as the *Haemonchus contortus* (Kaplan *et al*., 2004; Burke and Miller, 2008; Rumosa Gwaze *et al*., 2010). The *H. contortus* parasite brings losses to farmers since it causes decline in weight and body condition of livestock, at the same time leading to death of animals if not dealt with. Previous research has shown that goats are prone to *H. contortus* in the wet season (Kaplan *et al*., 2004; Rumosa Gwaze *et al*., 2010). Wet seasons are periods where the development of the *H. contortus* is at its utmost highest compared to dry seasons. However, findings from the current study indicate that FAMACHA scores declined and faecal egg counts increased with increased periods of water deprivation. This can be due to nutrition that help to boost the immunity of goats against parasites. It is necessary to recall that, goats tend to consume less feed when water resources are limited since they budget the available water to ensure efficient metabolism for maintenance (Adogla-Bessa and Aganga, 2000; Silanikove, 2000). Therefore, when water deprivation periods were increased, goats tended to have low FAMACHA scores and high faecal counts. Results from the current study can be supported by finding by Kahiya *et al*. (2003), who reported worm burdens reduced by 34 % when Boer goats were supplemented by *Acacia karroo*. In addition, the correlations from the current study indicate an increase in water deprivation periods result to low body condition scores and large faecal egg counts.

Findings that blood glucose, creatine kinase and cholesterol increased as the water deprivation period was increased was expected. This is because, periods of water deficit result to low blood water levels resulting in increased concentration of blood constituent (Casamassima *et al*., 2008). This is influenced by that, goats minimize water activities in the body when water resources are scarce to ensure water is largely channelled for metabolism, resulting in small blood water levels. Such small blood water levels are more of a concern for lactating does since a significant amount of water is required in the synthesis of milk (Abioja *et al*., 2014). It has been reported that, increased water deprivation periods reduce milk production by about 50 % (Aganga, 1992). Results from the current study are in agreement with results by Jaber *et al*. (2004), who reported increased levels of blood glucose, creatine, urea and cholesterol from Awassi sheep subjected to varying periods of water deprivation up to 4 days. Such increase in blood glucose, creatinine, urea and cholesterol is related to that, water deprivation negatively alters endocrine and metabolic balance when goats are facing water deficit, thereby causing large concentration in blood constituents (Casamassima *et al*., 2008).

6.5 Conclusions

It was concluded that water deprivation influence body condition scoring, body weight, faecal egg counts, FAMACHA and blood metabolites, thereby impacting on the nutritional status of Nguni goats. In general, goats deprived water over 0 hours resulted in largest body condition scoring, body weight and FAMACHA scores. At the same time, goats deprived of water for 48 hours resulted in the largest faecal egg counts, including blood metabolites tested. Pearson's correlations explained a decline in body condition score, body weight and FAMACHA score as the water deprivation period was increased, whereas increased periods of water deprivation explained an increase in faecal egg counts. Twenty four hour periods of water deprivation can be set as a threshold considering that faecal egg counts and FAMACHA were more severe at 48 h periods of water deprivation. Further studies can be done to monitor the nutritional status of various other common goats found in the southern African region. Such breeds can also be subjected to varying water deprivation periods to monitor breeds that best withstand future water constraints to help secure the future of the livestock industry.

6.6 References

Abioja, M.O., Osinowo, O.A., Abiona, J.A., Sodipe, O.G., 2014. Water balance and some blood parameters in water-restricted goats during hot-dry season, Slovakian Journal of Animal Science, 47(3): 149-156.

Adogla-Bessa, T. and Aganga, A.A., 2000. Responses of Tswana goats to various lengths of water deprivation, South African Journal of Animal Science, 30(1).

Aganga A.A., 1992. Water utilization by sheep and goats in northern Nigeria. World Animal Review, 73: 9-14.

Ahmed, M.M.M., El-Kheir, I.M., 2004. Thermoregulation and water balance as affected by water and food restrictions in Sudanese desert goats fed good-quality and poor-quality diets. Tropical Animal Health and Production, 36: 191–204.

Akingbade, A.A., Nsahlai, I.V., Bonsi, M.L.K, Morris, C.D. and du Toit, L.P., 2001. Reproductive performance of South African indigenous goats inoculated with DHP-degrading rumen bacteria and maintained on *Leucaena leucocephala*-grass mixture and natural pasture, Small Ruminant Research, 39: 73-85.

Alamer, M., 2006. Physiological responses of Saudi Arabia indigenous goats to water deprivation, Small Ruminant Research, 63: 100–109.

Burke, J.M. and Miller, J.E., 2008. Use of FAMACHA system to evaluate gastrointestinal nematode resistance/resilience in offspring of stud rams, Veterinary Parasitology, 153(1–2): 85–92.

Casamassima, D., Pizzo, R., Palazzo, M., D'Alessandro, A.G., Martemucci, G., 2008. Effect of water restriction on productive performance and blood parameters in comisana sheep reared under intensive condition, Small Ruminant Research, 78(1–3): 169–175.

Gerhart, K. L., White, R. G., Cameron, R. D. and Russell, D. E., 1996. Estimating fat content of caribou from body condition scores, The Journal of Wildlife Management, 60(4: 713-718.

Jaber, L.S., Habre, A., Rawda, N., AbiSaid, M., Barbour, E.K. and Hamadeh, S.K., 2004. The effect of water restriction on certain physiological parameters in Awassi sheep, Small Rumininant Research, 54: 115–120.

Kahiya, C., Mukaratirwa, S. and Thamsborg, S.M., 2003. Effects of Acacia nilotica and *Acacia karoo* diets on Haemonchus contortus infection in goats, Veterinary Parasitology, 115(3): 265–274.

Kaplan, R.M., Burke, J.M., Terrill, T.H., Miller, J.E., Getz, W.R., Mobini, S., Valencia, E., Williams, M.J., Williamson, L.H., Larsen, M. and Vatta, A.F., 2004. Validation of the FAMACHA© eye colour chart for detecting clinical anaemia in sheep and goats on farms in the southern United States, Veterinary Parasitology, 123: 105–120.

Masikati, P., 2010. Improving the water productivity of integrated crop-livestock systems in the semi-arid tropics of Zimbabwe: an ex-ante analysis using simulation modelling. Retrieved January 17, 2012, from http://www.zef.de/fileadmin/webfiles/downloads/zefc_ecology_development/eds_78_masikati_text.pdf.

Ndlovu, T., Chimonyo, M., Okoh, A.I., Muchenje, V., Dzama, K. & Raats, J.G., 2007. Assessing the nutritional status of beef cattle: current practices and future prospects. African Journal Biotechnology, 6: 2727-2734.

Pambu-Gollah, R., Cronje, P. B. and Casey, N. H., 2000. An evaluation of the use of blood metabolite concentrations as indicators of nutritional status in free-ranging indigenous goats, South African Journal of Animal Science, 30(2).

Rumosa Gwaze, F., Chimonyo, M and Dzama, K., 2010a. Nutritionally-related blood metabolites and faecal egg counts in indigenous Nguni goats of South Africa. South African Journal of Animal Science, 40: 480-483.

Rumosa Gwaze, F., Chimonyo, M. and Dzama, K., 2009. Communal goat production in Southern Africa: A review, Tropical Animal Health and Production, 41: 1157–1168.

Rumosa Gwaze, F., Chimonyo, M. and Dzama, K., 2010b. Relationship between nutritionally-related blood metabolites and gastrointestinal parasites in Nguni goats of South Africa, Asian-Australasian Journal of Animal Sciences, 23(9): 1190-1197.

SAS, 2010. SAS/STAT Software Release 9.3. SAS Institute Inc., Cary, North Carolina, USA.

Sejian, V., Maurya, V.P. and Naqvi, S.M.K., 2010. Adaptability and growth of Malpura ewes subjected to thermal and nutritional stress, Tropical Animal Health and Production, 42: 1763–1770.

Silanikove, M., 2000. The physiological basis of adaptation in goats to harsh environments, Small Ruminant Research, 35(3): 181–193.

Stella, A.V., Paratte, R., Valnegri, L., Cigalino, G., Soncini, G., Chevaux, E. Dell'Orto, V. and Savoini, G., 2007. Effect of administration of live Saccharomyces cerevisiae on milk production, milk composition, blood metabolites, and faecal flora in early lactating dairy goats, Small Ruminant Research, 67: 7–13.

CHAPTER 7: Influence of water restriction and water salinity on the nutritional status of Nguni goats

Abstract

The objective of the study was to determine the influence of varying levels of water restriction and water salinity on body condition scoring, body weight, faecal egg counts, FAMACHA scores, and blood metabolites of Nguni goats. Thirty six Nguni does (initial weight 18±3.2 kg) were used in the study. The goats were housed in individual cages and subjected to six levels of water restriction (2000; 1800; 1600; 1400; 1200 and 1000 mL), including three levels of water salinity (11; 5.5 and 0 g/L), with *ad libitum* access to *Medicago sativa* hay. Body condition scoring (BCS), body weight (BW), FAMACHA scores and faecal egg counts (FEC) were determined weekly. Blood metabolites (glucose, creatine, urea and cholesterol) were determined on the last day of the experiment. The BCS and FAMACHA scores increased quadratic to the peak, and later declined beyond 80 % of water restriction for goats subjected to 0 and 5.5 g/L of water salinity (P <0.05). The BW increased quadratic as the level of water restriction was decreased across all water salinity levels tested (P <0.01). The FEC decreased linearly as the level of water restriction decreased for both 0 and 5.5 level of water salinity (P <0.05). Creatine decreased quadratic as the level of water restriction was decreased across all water salinity levels tested (P <0.05). There was a linear relationship between urea and water restriction for goats subjected to 0 g/L of water salinity (P <0.05; Table 7.4). There was a linear decrease in urea as the level of water restriction was decreased for goats subjected to 5.5 g/L of water salinity (P <0.05). It was concluded that water restriction and water salinity reduced body condition

scoring, body weight, FAMACHA, and increased faecal egg counts, creatine and urea as the water restriction level was increased, thereby influencing the nutritional status of Nguni goats.

***Key words*:** water restriction, water salinity, goats, blood metabolites

7.1 Introduction

The scarcity of drinking water for goats is a topical issue globally. This is because, goats access drinking water from available water sources such as rivers, dams and boreholes (McGregor, 2004a). Water supply for goats from such water sources is largely poor in quantity and quality, not enough to meet the daily requirements for goats. As such, goats lose condition more in dry seasons during which water scarcity becomes severe. Poor water resources result in poor body condition, reduced weight gain, anaemia, large faecal egg counts and negatively alters the endocrine and metabolic balance resulting in increased blood profiles such as glucose, creatinine, urea and cholesterol levels (Casamassima *et al*., 2008; Rumosa Gwaze *et al*., 2010a). Body condition scoring is the most applicable measure that farmers can use to manage body reserves in goats because it is quick and easy (Rumosa Gwaze *et al*., 2009). To quantify the health status of goats, farmers can use the FAMACHA system which is widely used to monitor the level of anaemia in goats. This includes faecal egg counts, all of which affect the nutritional status for goats (Kaplan *et al*., 2004; Rumosa Gwaze *et al*., 2010b). Other accurate indicators useful in predicting and avoiding metabolic shortages blood metabolites (Caldeira *et al*., 2007). These have been reported as accurate measures of monitoring the nutritional status of goats since they involve contents of the blood stream (Caldeira *et al*., 2007; Rumosa Gwaze *et al*., 2010).

Goats have been reported to apply adaptive mechanisms that help ensure water availability during periods where drinking water resources for goats are poor. These include saving the available water in extracellular spaces of the rumen to help ensure sufficient metabolic water available when water resources do not meet the daily requirements for goats. Where water resources are saline, goats tend to minimize drinking habits when to help minimize water losses through urine since saline waters contain large amounts of sodium. Subjecting goats to various levels of water restriction and water salinity has been explored in goats from tropical regions to monitor their nutritional status (Attia-Ismail *et al*., 2008; Casamassima *et al*., 2008). However, this subject has not been explored for goats found in the southern African region such as the Nguni goat genotype common amongst farmers. Since water challenges are projected to intensify in the near future (Mabhaudhi *et al*., 2013; News24, 2014), knowledge pertaining water stress for common goat breeds of southern Africa can be useful in understanding the extent of adaptability of goats to water challenges. This is subject is critical so as to help farmers efficiently manage water resources, at the same time maintaining the best nourishment for goats even in dry periods where water resources are poor. The objective of the current study was to determine the influence of varying levels of water restriction and water salinity on body condition scoring, body weight, FAMACHA scores, faecal egg counts, including blood metabolites of Nguni goats. It was hypothesized that, varying levels of water restriction and water salinity influence body condition scoring, body weight, FAMACHA scores, faecal egg counts, including blood metabolites of Nguni goats.

7.2. Materials and Methods

7.2.1 Study site and ethical consideration

The experiment was conducted at Ukulinga Research farm in Pietermaritzburg, South Africa. The farm lies 29°40′ S, 30°24′ E with an elevation of about 775 m above sea level. Daily temperatures average 30 °C. Mean annual rainfall is 735 mm, falling mostly in summer with light to moderate frost occurring occasionally in winter (Akingbade *et al*., 2001). The experiment was conducted in compliance with the standards required by the Animal Ethics Committee of the University of KwaZulu-Natal (Reference No. 072/14/Animal).

7.2.2 Goat management, diets and experimental design

Goat management, diets and experimental design was as described in section 5.2.2.

7.2.3 Blood collection

Blood collection was as described in section 6.2.3.

7.2.4 Measurements

7.2.4.1 Body condition scoring

Body condition scoring was as described in section 6.2.4.1.

7.2.4.2 Body weight

Body weight determination was as described in section 6.2.4.2.

7.2.4.3 Faecal egg counts

Faecal egg counts were as described in section 6.2.4.3.

7.2.4.4 FAMACHA scores

FAMACHA scoring was as described in section 6.2.4.4.

7.2.4.5 Blood metabolites

Blood metabolites were as described in section 6.2.4.5.

7.2.5 Statistical analyses

Data on BCS, BW, FAMACHA scores and FEC were analysed using the GLM procedure of SAS (2010). Differences between least square means were tested using the PDIFF option of SAS (2010). The following model was used:

$Y_{ij} = \mu + R_i + S_j + (R \times S)_{ij} + E_{ij}$, where:

Y_{ij}- was the response variable

μ - was the overall mean common to all observations

R_i - was the effect of water restriction

S_j - was the effect of water salinity

$(R \times S)_{ij}$ - was the interaction between water restriction and water salinity

E_{ij}- was the residual error

The PROC REG of SAS (2010) was used to determine the relationships between water restriction together with water salinity on BCS, BW, FAMACHA scores and FEC.

7.3 Results

7.3.1 BCS, BW, FAMACHA and FEC

Relationships between BCS, BW, FAMACHA and FEC with water restriction together with water salinity are shown in Table 7.1. There was a quadratic relationship between BCS and FAMACHA scores with water restriction for goats subjected to 0 and 5.5 g/L of water salinity (P <0.05; Table 7.1). The BCS and FAMACHA peaked, and later declined beyond 80 % of water restriction for goats subjected to 0 and 5.5 g/L of water salinity (Figure 7.1). There was a quadratic relationship between BW and water restriction across all water salinity levels (P <0.01; Table 7.1). The BW increased as the level of water restriction decreased for both 0 and 5.5 level of water salinity (Figure 7.1). There was a linear relationship between FEC and water restriction level together with 0 g/L of water salinity (P <0.5: Table 7.1). The FEC declined as the level of water restriction decreased for each level of water salinity (0 and 5.5 g/L) (Figure 7.1).

7.3.2 Blood metabolites

Relationships between glucose, creatine, urea and cholesterol with water restriction together with water salinity are shown in Table 7.2. There was a quadratic relationship between creatine and water restriction across all water salinity levels tested (P <0.05; Table 7.2). The creatine decreased as the level of water restriction was decreased across all water salinity levels tested (Figure 7.2). Urea decreased steadily as the level of water restriction was decreased for goats subjected to 5.5 g/L of water salinity.

7.4 Discussion

Findings that body condition scoring and body weight scores peaked at 80 % of water

Table 7.1: Relationships between water restriction and water salinity on BCS, BW, FAMACHA scores and FEC of Nguni goats

Parameter	Water salinity (g/L)	Water restriction (%)						SEM	Regression coefficient		R-square	Sig
		50	60	70	80	90	100		Linear	Quadratic		
BCS	0	2.5	2.5	2.6	3.5	3.3	2.8		0.120	-0.00071	0.17	*
(Scale 1-5)	5.5	2.5	2.5	3.1	3.1	2.9	2.6	0.22	0.132	-0.000848	0.12	*
	11	2.4	2.8	2.6	2.5	2.5	2.5					NS
BW (kg)	0	18.8	26.5	24.8	25.6	25.8	24.1		1.111	-0.00693	0.20	**
	5.5	16.8	19.6	22.9	26.6	22.9	21.9	1.25	1.358	-0.00830	0.46	**
	11	14.1	13.8	18.4	16.4	10.1	11.4		0.885	-0.00641	0.25	**
FAMACHA	0	2.5	2.9	3.1	3.6	3.0	2.9		0.169	-0.00107	0.22	**
(Scores 1-5)	5.5	2.8	3.1	3.0	3.6	3.5	3.0	0.27	0.126	-0.000781	0.10	*
	11	3.1	3.0	3.5	3.8	3.5	3.3					NS
FEC (EPG)	0	287.5	100.0	100.0	62.5	25.0	12.5		-24.098		0.30	*
	5.5	162.5	87.5	87.5	100.0	87.5	62.5	50.27				NS
	11	100.0	25.0	100.0	187.5	187.5	50.0					NS

Abbreviations: BCS: body condition scoring, BW: body weight, SEM: standard error of mean, FEC: faecal egg counts

Sig: significance

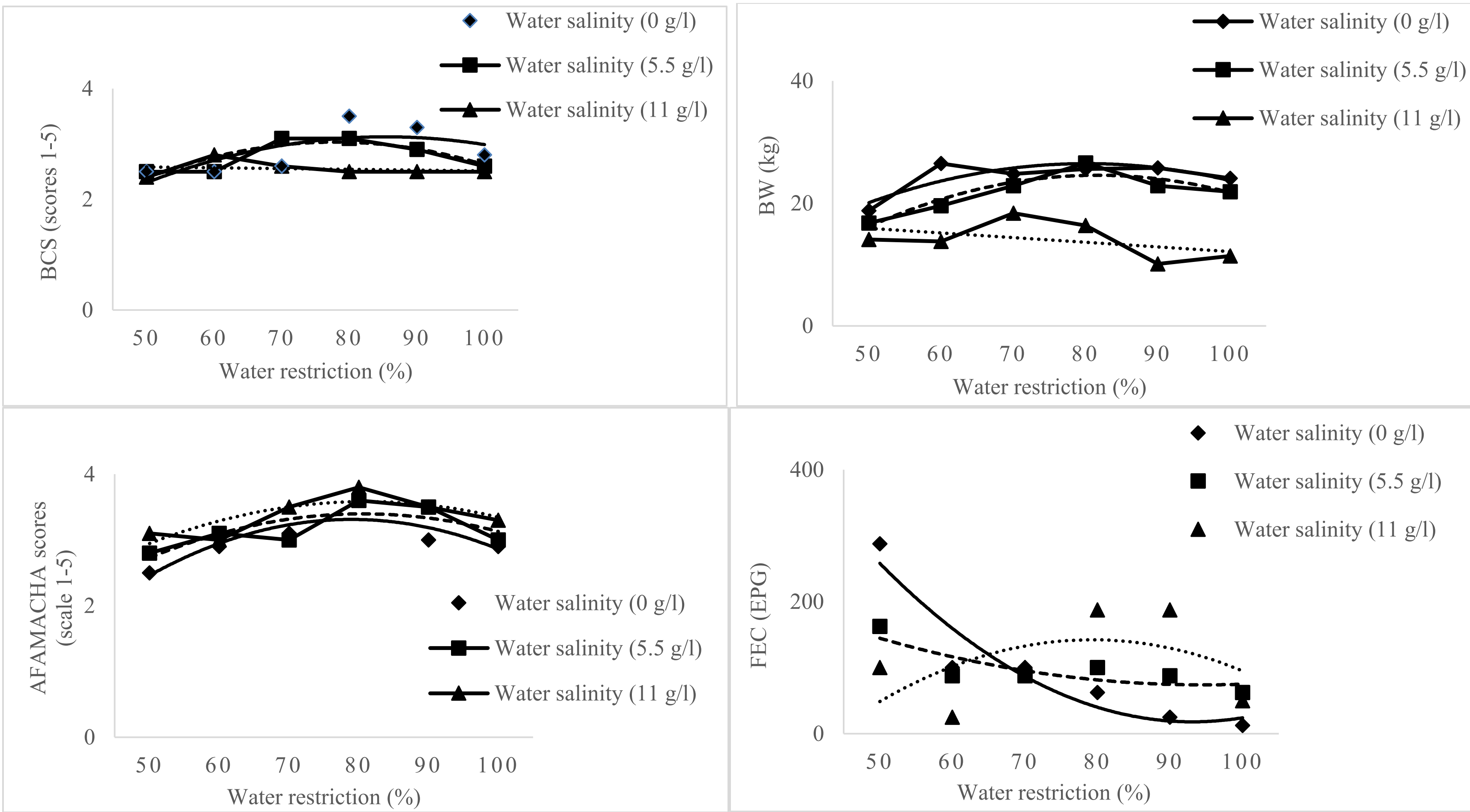


Figure 7.1: Influence of water restriction and water salinity on BCS, BW, FAMACHA scores and FEG in Nguni does

Table 7.2: Effect of water restriction and water salinity on blood metabolites

Parameter	Water salinity (g/L)	Water restriction (%)						SEM	Regression coefficient		R-square	Sig
		50	60	70	80	90	100		Linear	Quadratic		
Glucose	0	98.5	93.0	85.0	84.0	89.0	75.0					NS
	5.5	106.0	95.0	85.5	87.0	70.0	71.5	7.98				NS
	11	113.5	85.5	89.5	95.5	89.5	75.0					NS
Creatine	0	3.8	2.2	1.2	1.6	0.6	0.3		-0.235	0.00116	0.86	*
	5.5	2.4	1.5	0.5	0.8	1.0	0.8	0.33	-0.254	0.00151	0.74	**
	11	2.9	1.2	0.9	1.6	0.4	1.1		-0.263	0.0016	0.52	*
Urea	0	23.0	22.5	25.0	24.5	21.5	22.0					NS
	5.5	29.5	23.5	20.5	21.5	17.0	22.5	3.49	-1.532		0.45	*
	11	27.0	26.5	23.5	20.5	18.5	20.0					NS
Cholesterol	0	59.0	61.5	54.5	51.5	51.5	46.5					NS
	5.5	80.5	74.0	60.0	55.5	54.5	46.0	17.73				NS
	11	114.0	74.0	68.0	65.0	46.5	49.0					NS

Sig: significance

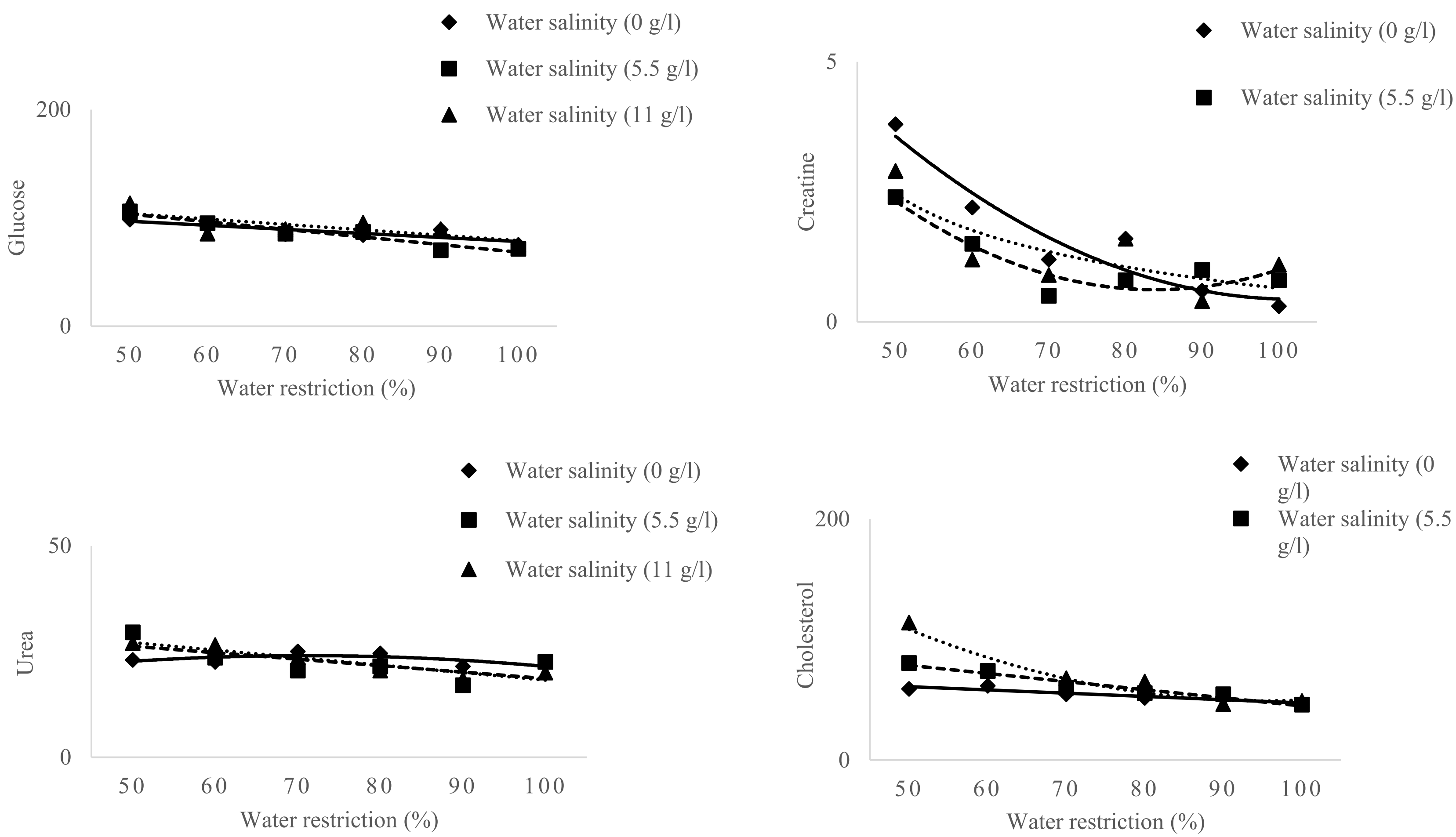


Figure 7.2: Influence of water restriction and water salinity on glucose, creatine, urea and cholesterol in Nguni does

restriction for 0 and 5.5 g/L of water salinity were expected. Goats tend to have better nourishment when water resources are sufficient (Silanikove, 2000). Goats with large body weight clearly indicate a state of nourishment measured by body condition scoring (Sezenler *et al*., 2011). It has been reported that, sufficient water supply to the goats encourage intake, thereby improving body weight and body condition of animals. Results from the current study are in agreement with Abioja *et al*. (2010), who reported a decrease in weight gain of West African Dwarf and Red Sokoto goats as the water restriction level was increased. Such results were due to less dry matter intake, considering that water intake is positively correlated to feed intake. At times, goats consume large quantities of water to satisfy excessive thirst rather than ensuring maximum productivity, hence a peak for body weight resulted at 80 % of water restriction level in the current study. Such results are due to that, large amounts of water result in less retention time of feed in the rumen, favouring reduced feed efficiency. On the other hand, various authors have reported several tolerance ranges for salinity in drinking water of small ruminant. Such thresholds consider a tolerance range of 8500 to 12300 mg of total dissolved solids for sheep and goats (McGregor, 2004a; Yape Kii and Dryden, 2005; Attia-Ismail *et al*., 2008). Salts are essential in the absorption of several nutrients in the small intestines (Maldonado-Valderrama *et al*., 2011). This means, providing animals with adequate salt helps in maximizing the nourishment utilization of energy, protein, and some minerals. When goats consume high levels of saline water, body weight tends to decline (Yape Kii and Dryden, 2005). Findings that goats from the current study resulted to small body weight at 11 g/L of water salinity is in agreement with previous studies. Such results can be related to small intakes that result since higher levels of water salinity minimize water intake to help manage salt levels in the body through urinary excretions. Such limits impact on the nourishment of goats.

The amount of gastro-intestinal parasite loads in goats and the level of anaemia are evaluated using the faecal egg counts and the FAMACHA system, respectively (Kaplan *et al*., 2004; Burke and Muller, 2008). There is a positive relationship between the FAMACHA system and faecal egg counts which all contribute to detecting the health condition for goats (Rumosa Gwaze *et al*., 2010). Reports have shown that the susceptibility of goats to anaemia and gastro-intestinal parasites is due to the scarcity of input resources for goats, particularly during dry seasons. Similar findings from the current study depicted an increase in FAMACHA scores, whereas faecal egg counts reduced as the level of water restriction was reduced. This is because; water availability encourages intake which contributes towards the nourishment of goats, hence goats remain in good body condition during wet seasons when input resources are abundant. On the other hand, findings that FAMACHA score increased as water salinity levels were increased can be linked to the fact that, salts help to improve nutrient absorption (Maldonado-Valderrama *et al*., 2011). At the same time, parasite infestations tend to negatively affect nourishment in goats since amino acids absorbed are normally used by parasites instead of being used up to build albumin for goats.

Findings that goats tended to have more concentration of blood constituents such as creatine and urea were expected. Casamassima *et al*. (2008) reported that, a deficient water supply negatively alters the endocrine and metabolic balance; an increase in blood glucose, creatinine, urea, and cholesterol concentrations. The observed increase in blood urea concentration as the level of water restriction increased can be attributed to less excretion that goats adapt to when faced with water challenges, leaving the blood concentrated compared to when drinking water is highly available for goats. On the other hand, periods of water deficit result to water being reabsorbed to accompany sodium absorption in the colon, resulting in the return of water to the blood. Since glucose and cholesterol remained unchanged across water restriction and water salinity levels tested in the current study means the animals were able to maintain the blood components by drawing water from other tissues into the blood system. Such results are in agreement with Abioja *et al*. (2014). It has been reported that, the absence of a significant effect in blood constituents of goats subjected to varying levels of water restriction can be linked with the superiority in adaptability of goats to water shortage (Abioja *et al*., 2014).

7.5 Conclusions

Water restriction and water salinity influenced body condition scoring, body weight, faecal egg counts, FAMACHA and some blood metabolites, thereby impacting on the nutritional status of Nguni goats. In general, body condition scoring and FAMACHA peaked at 1600 mL of water restriction for goats subjected to 0 and 5.5 g/L of water salinity. Body weight increased as the water restriction level was decreased, for goats subjected to 0 and 5.5 g/L of water salinity. Faecal egg counts increased as the water restriction level was increased, for goats subjected to 0 g/L of water salinity. Creatine declined as water restriction level was decreased, across all water salinity levels tested. Urea declined steadily as the water restriction level was decreased for goats subjected to 5.5 g/L of water salinity. The threshold for water restriction can be set at 1600 mL, with water salinity set at 5.5 g/L considering that the nutritional status of goats is not compromised. Further studies can be done to monitor the nutritional status of various other common goat breeds found in southern African region. Such breeds can be subjected to varying levels of water restriction and water salinity to monitor breeds that best withstand water stress projected to constrain the livestock industry in the future.

7.6 References

Abioja, M.O., Osinowo, O.A., Abiona, J.A., Sodipe, O.G., 2014. Water balance and some blood parameters in water-restricted goats during hot-dry season, Slovakian Journal of Animal Science, 47(3): 149-156.

Abioja, M.O., Osinowo, O.A., Adebambo, O.A., Bello, N.J. and Abiona, J.A., 2010. Water restriction in goats during hot-dry season in the humid tropic: feed intake and weight gain, Annales de Zootechnie 59, 195–203.

Akingbade, A.A., Nsahlai, I.V., Bonsi, M.L.K., Morris, C.D. and du Toit, L.P., 2001. Reproductive performance of South African indigenous goats inoculated with DHP-degrading rumen bacteria and maintained on Leucaena leucocephala/grass mixture and natural pasture, Small Ruminant Research, 39(1): 73–85.

Attia-Ismail, S.A., Abdo A.R. and Asker, A.R.T., 2008. Effect of salinity level in drinking water on feed intake, nutrient utilization, water intake and turnover and rumen function in sheep and goats, Egyptian Journal of Sheep and Goat Sciences, 3(1): 77–92.

Burke, J.M. and Miller, J.E., 2008. Use of FAMACHA system to evaluate gastrointestinal nematode resistance/resilience in offspring of stud rams, Veterinary Parasitology 153: 85–92.

Caldeira, R.M., Belo, A.T., Santos, C.C., Vazques, M.I. and Portugal, A.V., 2007. The effect of long-term feed restriction and over-nutrition on body condition score, blood metabolites and hormonal profiles in ewes, Small Ruminant Research, 68: 242–255.

Casamassima, D., Pizzo, R., Palazzo, M., D'Alessandro, A.G. and Martemucci, G., 2008. Effect of water restriction on productive performance and blood parameters in comisana sheep reared under intensive condition, Small Ruminant Research 78: 169–175.

Kaplan, R.M., Burke, J.M., Terrill, T.H., Miller, J.E., Getz, W.R., Mobini, S., Valencia, E., Williams, M.J., Williamson, L.H., Larsen, M. and Vatta, A.F., 2004. Validation of the FAMACHA© eye colour chart for detecting clinical anaemia in sheep and goats on farms in the southern United States, Veterinary Parasitology, 123: 105–120.

Mabhaudhi, T., Modi, A.T. and Beletse, Y.G., 2013. Growth, phenological and yield responses of a Bambara groundnut (Vigna subterranea L. Verdc) landrace to imposed water stress: II. Rain shelter conditions Water South Africa, 39: 191–198.

Maldonado-Valderrama, J., Wilde, P., Macierzanka, A. and Mackie, A., 2011. The role of bile salts in digestion, Advances in Colloid and Interface Science 165: 36–46.

McGregor, 2004a. The use and macro-mineral content of saline water for goat production, South African Journal of Animal Science, 34(1): 215-218.

McGregor, B.A., 2004b. Water quality and provision for goats. A report for the Rural Industries Research and Development Corporation. RIRDC Publication No.04/036.Rural Industries Research and Development Corporation, Canberra.

News24, 2014. SA a water-scarce country - Zuma. [Online] Available from: http://www.news24.com/SouthAfrica/News/SA-a-water-scarce-country-Zuma-20141101. [Accessed: 10th November 2015].

Rumosa Gwaze, F., Chimonyo, M. and Dzama, K., 2009. Communal goat production in Southern Africa: A review, Tropical Animal Health and Production, 41: 1157–1168.

Rumosa Gwaze, F., Chimonyo, M and Dzama, K., 2010a. Nutritionally-related blood metabolites and faecal egg counts in indigenous Nguni goats of South Africa. South African Journal of Animal Science, 40: 480-483.

Rumosa Gwaze, F., Chimonyo, M. and Dzama, K., 2010b. Relationship between nutritionally-related blood metabolites and gastrointestinal parasites in Nguni goats of South Africa, Asian-Australasian Journal of Animal Sciences, 23(9): 1190-1197.

SAS, 2010. SAS/STAT Software Release 9.3. SAS Institute Inc., Cary, North Carolina, USA.

Sezenler T., Yildirir M., Ceyhan A., Yüksel M.A., Onal A.R., and Ozder M., 2011. The Effects of Body Condition Score and Age of Ewes on the Reproductive Performance in Kivircik, Sakiz and Gokceada Sheep, Journal of Animal Science Advances, 1(2): 94-99.

Silanikove, M., 2000. The physiological basis of adaptation in goats to harsh environments, Small Ruminant Research, 35(3): 181–193.

Yape Kii, W. and Dryden, G.McL., 2005. Effect of drinking saline water on food and water intake, food digestibility, and nitrogen and mineral balances of rusa deer stags (*Cervus timorensis russa*), Animal Science, 81: 99-105.

CHAPTER 8: General discussion, conclusions and recommendations

8.1 General discussion

The current study was designed to determine whether subjecting Nguni goats to stress factors (water deprivation, water restriction and water salinity) would impact on intake, growth performance and the nutritional status. First a survey was conducted to understand the main constraints that negatively impact on farmer opportunities. Varying levels of water deprivation on intake and growth performance were determined, including that on the nutritional status of Nguni goats to understand the thresholds that goats withstand without compromising productivity. Also, varying levels of water restriction and water salinity on intake and growth performance were determined, including that on the nutritional status of Nguni goats to understand thresholds that goats withstand without compromising productivity. The main hypothesis tested in the current study was that, water stress (water deprivation, water restriction and water salinity) influence intake, growth performance and the nutritional status of Nguni goats.

In Chapter 3, a survey was conducted to test whether Nguni goats kept by resource-poor farmers can contribute to farmers' livelihoods through opportunities that exist. Female farmers were the major role players with regards to feeding practices, including the responsibility for meat sales. Farmers did not milk goats, and was associated with that farmers were used to milking cows and goat milk is largely considered as an alternative for individuals that have allergies for cow milk. Farmers indicated they faced with water and feed resource shortages for goats, where female farmers were projected to face water shortages than male farmers. This included farmers that reside away from farm to likely face water challenges. The lack of water resources can be related to that, farmers largely depend on available input resources without supplementing during time of short supply especially farmers that reside far away from farms (Peacock, 2005). This is important to consider because, the availability of input resources such as water helps to improve the goat productivity.

Since water is a scarce input resource amongst farmers, as reported (Chapter 4), possible approaches to water challenges had to be explored. One of these includes subjecting goats to water deprivation since goats spend days without water, and travel as far as about 14 km in search for water points away from grazing areas (Masikati, 2010). Therefore, in Chapter 4, goats were subjected to varying levels of water deprivation to monitor whether such a stress factor will influence intake and growth performance of Nguni goats. The average daily water intake including the average daily feed intake were largest in goats deprived of water for 48 h. Goats deprived of water for 48 hours consumed more water relative to feed compared to those subjected to 24 hours of water deprivation. Average daily gain and feed conversion ratio declined more as the water deprivation period was increased. To ensure efficient use of water resources, one can deprive Nguni goats for 24 h considering that goats subjected to 48 hours of water deprivation resulted in negative growth.

Where water points are available, water is insufficient to meet their daily requirements, and contain considerable amount of dissolved solids referred to as water salinity that reduce the quality of water resources for goats (McGregor, 2004; Alamer, 2009). To cater for such constraints, in Chapter 5, varying levels of water restriction and water salinity were adopted to test whether they can influence intake and growth performance of Nguni goats. The average daily feed intake peaked and average daily gain, and later declined beyond 1600 mL of water restriction for goats subjected to 0 and 5.5 g/L of water salinity. This indicated that, more water consumed was not necessarily used to ensure growth but to satisfy thirst brought about by water deficit (Adogla-Bessa and Aganga, 2000). Threshold pertaining water restriction to Nguni goats can be set to 80 % of water restriction since further levels of water restriction do not seem to improve feed intake and growth performance.

In Chapter 6, varying levels of water deprivation were adopted to test whether they can influence the nutritional status of Nguni goats. Body condition scoring and body weight were largest for goats deprived of water for 0 h compared to those deprived of water for 24 and 48 h. This is because; the availability of water resources influences goats to efficiently utilize feed resources since water is a medium necessary to ensure metabolism. Faecal egg counts increased as the water deprivation period was increased. FAMACHA scores were largest for goats deprived of water for 0 and 24 h compared to those deprived of water for 48 h. Also, blood metabolites were smallest for goats deprived of water for 0 days, simply because water deprivation result to low blood water levels resulting in increased concentration of blood constituent (Casamassima *et al.*, 2008).

In Chapter 7, varying levels of water restriction and water salinity were adopted to test whether they can influence the nutritional status of Nguni goats. The body condition scoring and FAMACHA scores peaked, and later declined beyond 1600 mL of water restriction for goats subjected to 0 and 5.5 g/L of water salinity. Body weight increased as the level of water restriction decreased for both 0 and 5.5 level of water salinity. Faecal egg counts declined as the level of water restriction decreased for both 0 and 5.5 level of water salinity. Creatine decreased as the level of water restriction was decreased across all water salinity levels tested. Urea decreased steadily as the level of water restriction was decreased for goats subjected to 5.5 g/L of water salinity. It was concluded that water restriction and water salinity reduced body condition scoring, body weight, FAMACHA scores, and increased faecal egg counts, creatine and urea as the water restriction level was increased, thereby influencing the nutritional status of Nguni goats

8.2 Conclusions

Water deprivation, water restriction and water salinity influence intake, growth performance and the nutritional status of Nguni goats. The productivity of goats can be improved by ensuring efficiency of input resources for goats such as water, to improve farmer opportunities. To ensure efficient utilization of water resources, Nguni goats can be deprived of water for 24 h considering that goats subjected to 48 hours of water deprivation in the current study resulted in negative growth. Threshold pertaining water restriction to Nguni goats can be set to 1600 mL of water restriction since further levels of water restriction do not seem to improve feed intake and growth performance. Twenty four hour periods of water deprivation can be set as a threshold when monitoring the nutritional status of Nguni goats considering that faecal egg counts and FAMACHA were more severe at 48 h periods of water deprivation. The threshold for water restriction can be set at 1600 mL, with water salinity set at 5.5 g/L considering that the nutritional status of goats is not compromised.

8.3 Recommendations

The use of various other common goat breeds, other than the Nguni goat used in the current study need attention, as this widens the scope of water stress to help add knowledge pertaining intake, growth performance and the nutritional status of indigenous goats. It is also important to investigate the blood haematology including blood biochemistry to help ensure thorough understanding of the health status of common indigenous goats subjected to water stress. Also, the responses of goats to water stress needs understanding using direct observation using cameras to understand behavioural responses linked to water stress. Looking at water stress, one needs to also consider variation in climatic conditions of the southern African region.

8.4 References

Adogla-Bessa, T. and Aganga, A.A., 2000. Responses of Tswana goats to various lengths of water deprivation, South African Journal of Animal Science, 30(1): 87-91.

Alamer, M., 2009. Effect of water restriction on lactation performance of Aardi goats under heat stress conditions, Small Ruminant Research 84: 76–81.

Casamassima, D., Pizzo, R., Palazzo, M., D'Alessandro, A.G. and Martemucci, G., 2008. Effect of water restriction on productive performance and blood parameters in comisana sheep reared under intensive condition, Small Ruminant Research 78: 169–175.

Masikati, P., 2010. Improving the water productivity of integrated crop-livestock systems in the semi-arid tropics of Zimbabwe: an ex-ante analysis using simulation modelling. Retrieved January 17, 2012, from http://www.zef.de/fileadmin/webfiles/downloads/zefc_ecology_development/eds_78_masikati_text.pdf.

McGregor, 2004. The use and macro-mineral content of saline water for goat production, South African Journal of Animal Science, 34(1): 215-218.

Peacock, C., 2005. Goats: a pathway out of poverty, Small Ruminant Research 60: 179–186.

9: Appendices

Appendix 8.1: Survey questionnaire

The objective of the survey is to identify opportunities for resource-poor farmers to improve the contribution goat milk to rural livelihood.

Questionnaire number…………….. Enumerator name……………….
Municipality name………………… Community name……………….
Name of respondent……………….. Date…………………………….

A. HOUSE HOLD DEMOGRAPHY

A1. Head of the household/ inhloko yomuzi
a. Sex/ uUbulili: M□ F□ b. Marital status/ Isimosomshado: Married/ Ushadile □ Single/ akashadile□ Divorced/ Divosile□ Widowed/ ufelwe□
c. Age/ Iminyaka:<13□ <36□ ≥36□
d. Highest education level/ Izingalokufunda No formal education□ Grade1-7/Ibanga 1-7□ Grade8-12/ Ibanga8-12□ Tertiary/ Imfundo ephakeme□
A2. Religion/ Inkolo? Christianity/ amakrestu□ Traditional/ amasiko□ Moslem/ anasulumane□ Other/ okunye (specify/ cacisa)………………………………………………………………………………
A3. Is the head of the household resident on the farm/ Ingabe inhloko yomuzi ihlala ekhaya? Yes/Yebo□ No/ Cha□
A4. Principal occupation/ indlela esemqoka yokuziphilisa?...

A5.What is the size of the household/ Mangakhi amalungu omndeni?

Age group/ ngokweminyaka	Males/ Abesilisa	Females/ Abesifazane
Children/ Izingane<13 years		
Youths / Abasha(<36 years)		
Adults/ Abadala (≥36 years)		

A6. What type of livestock species do you keep/ Hloboluni lwemfuyo enilifuyile? (Rank 1 as the most important specie)

Class	Cattle/ Izinkomo	Goats/ Izimbuzi	Sheep/ Isiklabhu	Pigs/ Izingulube	Chickens/ Izinkukhu	Other /Okunye(specify/cacisa)
Number /Inani						
Rank/ Hlela						

A7. Do you keep goats/ Ingabe niyazifuya izimbuzi?Yes/ Yebo□ No/Cha□
A8. If not, why/ Uma uthicha, veza isizathu?...

A9. If yes, how did you acquire your goats/ Uma uthiyebo, wazitholakanjaniizimbuzizakho? Inherited/ Ifa□ Exchanged/ Ngokushintshanisa□ Bought/ wazithenga□ Other/ okunye (Specify/ cacisa)……..

A10. Who is the owner of the goats/ Ubani umnikazi wezimbuzi? Mother/ umama□ Father/ ubaba□ Children/ Izingane□ Other/ okunye (specify/ cacisa)…………………………………………………

A11.If goats were bought, where did you get the money to purchase them/ Uma ngabe izimbuzi nazitholan gokuzithenga, nayithola kanjani imali yokuzithenga? Bank/ Ebhange (loan)□ Own capital/ Ngemaliyakho□ Other/ Okunye(specify?Cacisa)...

A12. What role(s) does each family member play in goat production/ Veza indima edlalwa ilunga lomndeni ekukhiqizweni kwezimbuzi? (Tick one or more/ Maka okukodwa okanye ngaphezulu)

Role/Indima	Adults/ Abadala		Children/ Izingane		Hired labour/ Abaqashiwe
	Male/ Abesilisa	Female/ Abesifazane	Boy/ Umfana	Girl/ Intombazane	
Feeding/ Ukuziphakela					
Penning goats/ Ukuzivalela izimbuzi					
House construction and maintenance/ Ukwakha nokunakekela izindlu zezimbuzi					
Mating management/ Ukuzinakekela umazikhwelana					
Health management/ Ukunakekelwa ngokwezimpilo					
Purchasing/ Ukuthengwa kwezimbuzi					
Slaughtering/ Ukuhlinzwa					
Selling/ Ukudayiswa					
Other/ Okunye (specify/ cacisa)					

A13. Are youths interested in goat rearing/ Ingabe intsha inalo ugqozi ekufuyweni kwezimbuzi? Yes/ Yebo□ No/ Cha□

A14.Give a reason/ Nika isizathu?...

A15. Is foraging communal/ Ingabe izimbuzi zidlaesidlangalaleni? Yes□ No□

A16. If not, what is your land tenure system/ Uma uthi cha, veza uhlobo owatholangalo umhlaba wokudla izimbuzi zakho?..

A17. How much income does your household get per month/ Nithola malini ngenyanga? R................

A18. How many employed children do you have/ Zingaki izingane ezisebenzayo?...............................

A19. What is the wealth status of the household/? Very poor □ Poor □ Less poor □

B. GOATHERD COMPOSITION, PURPOSES AND FUNCTIONS

B1. What is the composition of your goat herd/ Veza izinhlobo zezimbuzi ozifuyile?

Productive stage/ izinga lokukhula	Breed/		
	Local/ Ezesintu	Crossbred/ ezixubile	Exotic/ Ezesilungu
Lactating females/ izinsikaziezincelisayo			
Suckling females (<4 months)/ izinsikazi ezinceliyo			
Suckling males (<4 months)/ izinyanile silisa elincelayo			
Weaned females (>4 months)/izinyanile sifazane elingasanceli			
Weaned males (>4 months)/ izinyanile silisa lingasanceli			
Breeding females (females after first kidding)/ umbuzi ekhwelwayo esikeyazala kanye			
Breeding males (bucks over 12 months)/ Imbuzi ekhwelayo engaphezukonyaka			
Castrates (castrated males older than 1 year)/ imbuzi etheniwe engaphezu konyaka			
Total			

B2. Why do you keep goats/ Uzifuyelani izmbuzi? (Tick one or more/ maka okunye noma okuningi) (Rank 1 as the most preferred use/ hlela eyokuqala njenngaleyo esetshenziswa kakhulu)

Reason/ Isizathu	Tick appropriate response/ Maka	Rank/ Hlela
Selling to raise income/ sizidayisela ukuthola imali		
Household consumption/ ukudla ekhaya		
Savings and investment/ Ukonga		

Manure/ umanyolo		
Socio-cultural functions (e.g. lobola)		
Family pride and status/ Isithunzi		
Others/ Okunye (specify/ cacisa)		

B3. What products from goats do you value most/ Umuphi umkhiqizo wezimbuzi obalulekile kunina? Milk/ Ubisi□ Meat/ Inyama□ Skin/ Isikhumba□ Manure/ Umanyolo□ Mohair/ Uboya□

B4. Give a reason/ Nika isizathu?...

B5. What do you do with goat products/ Nenzani ngomkhiqizo wembuzi?

Goat products/ Umkhiqizo wezimbuzi	Uses of goat products			
	Consumption/ Ukudla	Sale/ Ukudayiswa	Exchange/ Ukushintshaniswa	Other/ Okunye
Milk/ Ubisi				
Meat/ Inyama				
Skin/ Isikhumba				
Manure/ Umanyolo				
Mohair/ Uboya				

B6. What do you think farmers can do with goat products to improve income generation amongst rural households/ Ucabanga ukuthi yini engenziwa abafuyi ngomkhiqizo wezimbuzi ukuthola imali?...

B7. What do you think hinders such desires/ Ngabeiziphi izingqinamba?..

B8. Do you milk goats/ Niyazisenga izimbuzi? Yes/ Yebo□ No/ Cha□

B9. If yes, who does the milking/ Uma uthiyebo, ubani osengayo? Mother/umama□ Father/ ubaba□ Girls/ amantombazane□ Boys/ abafana□ Other/okunye□ (specify/ cacisa)………...

B10. If no, give a reason why you milk/don't milk goats/ umauthicha, nikaisizathu………………………………………………………………………………………..

B11. Are you aware of the value of goat milk/ ngabe uyazi ngokubaluleka kobisi lwembuzi? Yes/ Yebo□ No/ Cha□

B12. Explain your answer/ Chaza impendulo yakho...

B13. Are you willing to milk goats/Ngabe uyafunayini ukusenga izimbuzi?Yes/Yebo□ No/cha□

B14. If yes, explain? Uma uthiyebo, nika isizathu...

B15. If no, what is the reason you don't want to milk goats/ uma uthi cha, isiphi isizathu sokungafuni
ukuzisenga?...
B16.What are challenges that hinder you most from milking goats/ Iziphi izingqinamba ezikuvimbile ekusengeni izimbuzi?..
B17. What do you think can be done to overcome those challenges/ Yini engenziwa ukuxazulula lezizingqinamba?...
B18. Do your current goats provide you with enough household milk/ Ingabe izimbuzi onazo manje ziyakunika yini ubisi olwanele? Yes/ Yebo□ No/Cha□
B19. What do you think can be done to improve household milk from goats/ Yini engenziwa ukunyusa umkhiqizo wobisi lwezimbuzi?..
B20.Do you like goat or cow milk? / Ingabe uthanda amasi wezimbuzi noma amasi wenkomo?
Goat milk□ Cow milk□
B21. Give a reason/ Chaza……………………………………………………………………………….
B22. In your own view, what is the difference between goat and cow milk? / Ngokomcabango wakho, ingabe uyini umahluko phakathi kwamasi wezimbuzi namasi wenkomo?..
B23. Do you sell goat milk? / Ingabe uyawadayisa amasi wezimbuzi? Yes□ No□
B24. If yes, what do you consider when selling goat milk?/ Maukuthi uyawadayisa amasi wezimbuzi, ingabe ubukani emasini? Fresh milk□ Fermented milk□
B25. Explain your answer/ Chaza…………………………………………………………………………………

C. FEEDING AND MANAGEMENT

C1. Which goat production system are you using/ Hlobo luni enifuya ngalo izimbuzi?

Scavenging/ Zidle noma ikuphi	
Backyard/ Ziyavalelwa ekhaya	
Intensive/ Ziyavalelwa eplazini	

C2.Do you change your production systems with seasons/ Mgabe niyazishintsha yini izindkela zokufuya njalo ngesikhathi sonyaka?Yes/ Yebo□ No/ Cha□
C3. If yes, explain, umauthi yebo, chaza...
C4. Do you experience feed shortages/ Niyahlangabezana yini nesimo sokushoda kokudla kwembuzi? Yes/ Yebo□ No/ Cha□
C5. If yes, do you provide supplementary feeding/ Uma uthi yebo, niyaziphakela yini? Yes/ Yebo□ No/ Cha□
C6. How much supplementary feed do you give a goat per day/ Niziphakela ukudla okungakanani ngosuku?...........................kg/day
C7. What feed sources do you provide to your goats as supplementary feeds/ Ukuphi ukudla eniziphakela
kona?...

C8. If yes, what feed materials are available for your goats/ Uma uthiyebo, ukuphi ukudla okudliwa izimbuzi?

Season / Isikhathi sonyaka	Common feeds/ Ukudla okuxhaphakile	Condition of goats/
Summer season/ Ehlobo		
Winter season/ Ebusika		

C9. If yes, how do you prioritise feeding during feed shortages/ Uma uthi yebo, ngabe uziphakela kanjani izimbuzi ngesikhathi sokushoda kokudla?..

C10. What is the source of drinking water for your goats/ Ngabe amanzi ziwathola kanjani izimbuzi?...

C11. How often do your goats drink water/ Ziwaphuza kangaki amanzi izimbuzi?.............................

C12. How much water do you give your goats per day/ Uzipha kangaki amanzi izimbuzi zakho ngosuku?..

C13. Do you house your goats at night/ Ngabeniyazivalelayiniizimbuziebusuku? Yes/ Yebo No/ Cha□

C14. If yes, what building materials do you use? Uma uthi yebo, yakhiwe ngani indlu yezimbuzi..

Appendix 9.2: McMaster counting technique (for nematodes)

Principle

The McMaster counting technique is a quantitative technique to determine the number of eggs present per gram of faeces (e.p.g.). A flotation fluid is used to separate eggs from faecal material in a counting chamber (McMaster) with two compartments. The technique described below detects 50 or more e.p.g. of faeces.

Application

This technique can be used to provide a quantitative estimate of egg output for ematodes, cestodes and coccidia. Its use to quantify levels of infection is limited by the factors governing egg excretion.

Equipment

Beakers or plastic containers, balance, a tea strainer or cheesecloth, measuring cylinder, stirring device (fork, tongue depressor), pasteur pipettes and (rubber) teats, flotation fluid (see the Appendix to this handbook for formulation), McMaster counting chamber, microscope.

Procedure

(a) Weigh 4 g of faeces and place into Container 1.

(b) Add 56 mL of flotation fluid.

(c) Mix (stir) the contents thoroughly with a stirring device (fork, tongue blade).

(d) Filter the faecal suspension through a tea strainer or a double-layer of cheesecloth into Container 2.

(e) While stirring the filtrate in Container 2, take a sub-sample with a Pasteur pipette.

(f) Fill both sides of the McMaster counting chamber with the sub-sample.

(g) Allow the counting chamber to stand for 5 minutes (this is important)

(h) Examine the sub-sample of the filtrate under a microscope at 10 x 10 magnification.

(i) Count all eggs and coccidia oocytes within the engraved area of both chambers.

(j) The number of eggs per gram of faeces can be calculated as follows: Add the egg counts of the two chambers together. Multiply the total by 50. This gives the e.p.g. of faeces. (Example: 12 eggs seen in chamber 1 and 15 eggs seen in chamber 2 = (12 + 15) x 50 = 1350 e.p.g.)

(k) In the event that the McMaster is negative (no eggs seen), the filtrate in Container 2 can be used for the simple flotation method (section 3.2.2), steps f, g and h.

Appendix 5: Determination of blood metabolites

For the determination of total protein content, biuret reagent AE5-23 was allowed to complex with the peptide bonds of protein from the sample under alkaline condition to form a violetcoloured compound. Sodium potassium tartrate was used as an alkaline stabilizer, and potassium iodide was used to prevent autoreduction of the copper sulfate. The amount of the violet complex formed was proportional to the increase in absorbance when measured bichromatically at 544 nm/692 nm. For albumin, reagent AE5-2 was allowed to complex with the sample and the increase in absorbance which was measured bichromatically at 629 nm/692 nm, was proportional to the amount of albumin present in the sample. The rate of increase in absorbance, monitored bichromatically at 408 nm/486 nm, was directly proportional to the alkaline phosphatase activity when the sample was allowed to react with reagent RX1002. For the determination of inorganic phosphate, reagent AE5-18 was allowed to react with the sample and at completion of the reaction, the absorbance of the sample reagent mixture was read bichromatically at 340 nm/378 nm. The difference between these two absorbance values was proportional to the amount of phosphorus present in the sample. For the determination of calcium, Arsenazo was used, whilst xylidyl blue in an alkaline medium was used for the determination of magnesium. The colour intensities were read off bichromatically and were proportional to the amount of the mineral present in the sample. Glucose was analysed using the method described by Gochman and Schmitz (1972) where reagent NAE2-27 was used after enzymatic oxidation in the presence of glucose oxidase. The blood values were categorized into below, normal and above normal range considering the reference values as presented in Table 7.11-7.19 below.

Appendix 9.3: Conference attended

1. Poster presentation: Opportunities for resource-poor farmers to improve the contribution of Nguni goats to communal livelihoods, South African Society for Animal Sciences, 47th Biannual Congress, University of Pretoria, Gauteng, South Africa, 6-8 July 2014.
2. Poster presentation: Influence of water deprivation on intake and growth performance of Nguni goats, South African Society for Animal Sciences, 48^{th} Biannual Congress, University of Zululand, Empangeni, South Africa, 21-23 September 2015.

Appendix 9.4: Publications related to this thesis

1. Mpendulo, C.T. and Chimonyo, M., 2016. Influence of water deprivation on intake and growth performance of Nguni goats, Tropical Animal Health and Production, Manuscript number: TROP-D-15-01067.
2. Mpendulo, C.T., Chimonyo, M. and Zindove, T.J., 2016. Influence of water restriction and water salinity on feed intake and growth performance of Nguni does, Small Ruminant Research, Manuscript number: Rumin-D-15-7343R1.