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Comparative reproductive performance of Saanen and Toggenburg bucks raised under tropical environment

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Abstract

The objective of this study was to evaluate the effect of breed and age on scrotal measurements and semen characteristics of Saanen and Toggenburg bucks raised under extensive system in the tropic. The study was conducted using Toggenburg and Saanen bucks; the bucks were allocated into two different groups based on breed and age in 2 × 2 factorial completely randomized design. The body weight was determined using a hanging weighing scale expressed in kilogrammes (kg). Scrotal circumference and scrotal length were measured using metal measuring tape. Semen characteristics evaluated were volume, consistency, mass activity and progressive motility, live sperm cells, normal morphology and spermatozoa concentration. The current study found that breed of bucks had no influence on body weight, scrotal circumference, scrotal length, volume, mass activity, progressive motility, live sperm cells and sperm morphology. The study also found that Toggenburg bucks had higher semen consistency and spermatozoa concentration as compared with Saanen bucks. Therefore, it can be concluded that Toggenburg bucks can produce high number of total spermatozoa and as a result higher semen doses for artificial insemination purposes. Further studies with more number of animals are recommended.

Keywords Breed · Goat · Scrotal measurements · Semen characteristics

Introduction

Tropical goat breeds are well adapted to their environment in terms of traits such as disease resistance, heat resistance and ability to cope with poor quality feed (Peacock 1996). These traits enable them to survive and be productive in their environments. However, they are considered poor producers because of low milk and meat yield. Consequently, livestock improvement programmes in the tropical zones imported temperate goat breeds such as Saanen and Toggenburg with the purpose of improving milk yield (Peacock 1996).

In terms of performance between Saanen and Toggenburg in the temperate environment, Saanen surpasses Toggenburg in milk yield, body weight and some reproductive performances (Chandler et al. 1988; Mellado 2016). However, such differences might be altered when they are exposed to environments not similar to that of their place of origin, like in the tropics. It was previously reported that Toggenburg performs better than Saanen in the tropics in terms of milk production, because Toggenburg is well adapted to the tropical environment (Takahashi 2012), especially when kept under semi-intensive conditions. However, such comparison is yet to be elucidated in reproductive performance traits such as testicular traits and semen characteristics in these goat breeds in the tropics, and particularly in Kenya.

Generally, the setback of these temperate goat breeds is their poor adaptation to tropical environment in their ability to resist the effect of heat stress and other factors such as diseases. Heat stress caused by high ambient temperature can result in decrease growth, milk production and fertility in livestock (Takahashi 2012; Samal 2013). Heat stress can influence fertility by affecting most reproductive functions: spermatogenesis, oocyte development, oocyte maturation, early embryonic development, foetal and placental growth and lactation in mammalian species (Hansen 2009; Samal 2013).

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The testis is suspended in a scrotum outside the body in order to keep the temperature lower than core body temperature, which is required for normal spermatogenesis (Takahashi 2012). Scrotal circumference and testicular consistency, size and weight, are excellent indicators of sperm production capacity and spermatogenic functions (Marai et al. 2008). Exposure of goats to heat stress reduces scrotal volume, testicular consistency and sperm quality (Marai et al. 2004). Apart from heat stress, other factors which can influence reproduction in goats include breed, age, nutrition, individual animal and season (Noran et al. 1998).

Based on the above reasoning, breeding of goats whether using natural mating or artificial insemination requires proper selection of breeding buck and more especially when employing artificial insemination. Artificial insemination helps in increasing and disseminating genotypes of quality breeding stock; however, its success largely depends on the semen of the breeding buck. The breeding buck selection is the most critical decision for improvement of a herd (Ngoma et al. 2016). As a result, breeding soundness examination of the breeding bucks is essential for a good flock fertility. It includes all aspects related to scrotal measurements and semen evaluation which are important in management practices, especially for artificial insemination in goat breeding programme.

Despite the importance of these exotic goat breeds in the tropics, comparative information on their scrotal measurements and semen characteristics is still scarce. The objective of this study was to evaluate the effect of breed and age on scrotal measurements and semen characteristics of Saanen and Toggenburg bucks raised under tropical conditions.

Materials and methods

Experimental site

This study was conducted at the Tatton Agriculture Park (TAP), Egerton University, Njoro. Njoro area is approximately within latitude 00º 19'00" S and longitudes 36º 06'00" E, and at an elevation between 2168 m and 2800 m above sea level. The site receives monthly total rainfall of 86.3 mm, and its temperature varies between minimum of 10.2 and maximum of 23.3ºC (Wangui et al., 2018).

Experimental animals and design

The study was conducted using total of twelve healthy bucks. The bucks were divided into two groups, one group with six Toggenburg and the other group with six Saanen bucks. Within each group the bucks were further subdivided into two groups based on their age (one group between age of 1 and 2 years and the other group 3 and 6 years). The experimental design was 2 × 2 factorial design.

Management, housing and feeding of experimental goats

The bucks were managed under semi-intensive system. They were kept in stall to protect them from direct sunlight, rains and adverse weather conditions. They were fed on natural pastures and supplemented with mineral licks for sheep and goats (NutriFarm for Animal feed supplement industry, Thessaloniki, Greece), and water was given ad libitum throughout the experimental period.

Measurement of body weight and scrotal measurements

The body weight (BW) was determined using a round spring balance scale with maximum weight 150 kg (Hanson Company Ltd., Maidenhead, UK). Scrotal parameters measured were: scrotal circumference (SC) and scrotal length (SL). Both the SC and SL were measured using a flexible measuring tape in centimetres as described by Akpa et al. (2012). The SC was measured as the maximum dimension or largest diameter of the scrotum after pushing the testes firmly into the scrotum. The SL was measured as the distance along the caudal surface of the scrotum to its point of attachment to the tip of the scrotum.

Semen collection and evaluation

Semen collection Data on semen was collected once every week for a period of 7 weeks. Semen was collected using electro-ejaculator design for small ruminants (Lane Manufacturing, Denver, Colorado, USA). The collection procedures followed was according to instructions from the company. Briefly, a buck was restrained in a standing position and the urethral opening cleaned. Then the rectal probe was lubricated with a lubricating jelly and inserted in to the rectum of a restrained buck at approximately 10 cm. After insertion of the probe, the prostate gland was massage 8 to 10 times before the control button was applied to generate power. Thereafter, the control button of the instrument was pushed for 4–6 s, and power of 9 V was generated and held for 5–8 s and again brought to 0. This procedure was repeated after a rest period equal to the duration of electrical stimulation until ejaculation took place. During collection and examination, the semen was protected from cold shock and exposure to direct sunlight. Collecting tube was fitted to the artificial vagina to collect the semen. The temperature on the inner liners of the artificial vagina was kept between 42 and 45 °C while that of the collecting tube was maintained between 30 and 37 °C before semen collection to prevent cold shock to the sperm cells.

Semen evaluation The semen samples collected were evaluated for volume, consistency, mass activity, progressive motility, live sperm cells, concentration and normal morphology. Semen consistency, mass activity and progressive motility were evaluated as described by Steyn (2005). The semen volume and density were determined directly from the graduated transparent tube used for semen collection. The semen consistency was ranked as watery (0), thin milky (1), milky (2), thin creamy (3), creamy (4) and thick creamy (5). The mass activity was evaluated based on the wave motion (from a scale of 0–5) by viewing a drop of undiluted semen under power magnification (× 10 magnification) using a phase contrast microscope (Richter Optica, Model U2, China) mounted with a camera. Progressive motility was assessed by putting a drop of diluted semen on pre-warmed glass slide (25.4 × 76.2 mm) covered with a cover slip (22 × 22mm) (SailBoat Lab Co., Ltd., Zhejiang, China) and viewed under power magnification (× 40) of phase contrast microscope. Semen drop was mixed in saline solution (0.9% sodium chloride, manufactured by Abacus Parental Drugs Ltd., Kampala, Uganda). The progressive motility was evaluated as percentages from 0 to 100%, depending on the individual motility of the sperm. Sperm concentration was determined using the standard procedures with an aid of Neubauer improved haemocytometer (Marienfeld Company, Lauda-Königshofen, Germany) under phase contrast microscope at magnification power of (× 40). The sperm cells were counted in 5 smaller squares of Neubauer improved haemocytometer, and spermatozoa concentration per one millilitre was calculated using the formula: number of sperm cells counted in 5 smaller squares × 5×10^4 × dilution factor. The dilution rate of 1:200 semen to water was used. The sperm cell morphology and percent live/dead were evaluated using eosin-nigrosin (Hi-Tech Solutions, New Delhi, India). A mixture of 5 μl of spermatozoa and 10 μl eosin-nigrosin stains was smeared on a slide and allowed to air dry for 30 min; thereafter, two hundred sperm cells from different microscopic fields were examined under a phase contrast microscope (× 40 magnification).

Statistical analyses

The effect of breed and age on body weight, scrotal measurements and semen characteristics were analysed using analysis of variance (ANOVA) with general linear model (GLM) of SAS (Version 9.0). Correlation analysis among body weight, scrotal measurements and semen characteristics was analysed using Pearson's product-moment procedures of SAS (Version 9.0). Differences were considered significant at $P < 0.05$. The fixed effects were breed and age, while the dependent variables were semen consistency, semen volume, mass activity, progressive motility, sperm concentration, normal morphology, body weight, scrotal circumference and scrotal length. The following model was fitted for data analysis:

$$Y_{ijk} = \mu + B_i + A_j + (B{*}A)_{ij} + E_{ijk}$$

where Y_{ij} is the observation on the dependent variables, μ is the overall mean, B_i is the fixed effect of breed, A_j is the fixed effect of age, $(B * A)_{ij}$ is the interaction effect of breed and age and e_{ijk} is the random error.

Results

The findings on the effect of breed on body weight, scrotal and semen characteristics are presented in (Table 1). The results showed that there was no significant difference between the two breeds in terms of body weight and scrotal measurements. The breed effect was, however, observed in semen consistency and sperm concentration. Other semen characteristics such as volume, mass activity, progressive motility, live sperm cells and normal morphology were not affected by the breed.

The effect of the age of bucks on body weight, scrotal and semen characteristics are presented in (Table 2). Age of the bucks had significant effects on body weight, scrotal and semen characteristics. There was a significant difference ($P < 0.05$) between the young (1–2 years) and adults (3–6 years) in terms of their body weight, scrotal circumference and scrotal length. Additionally, semen consistency, mass activity, progressive motility and sperm concentration differed significantly ($P < 0.05$) in terms of age. The semen volume, live sperm cells and normal spermatozoa morphology were, however, not affected by age of the bucks. Interaction effects between breed and age were not significant for all the variables measured.

The correlation among body weight, scrotal and semen characteristics for the Toggenburg and Saanen dairy goat breeds are presented in (Table 3). The results shown that scrotal circumference, scrotal length and body weight had positive correlation among each other. Sperm concentration had a positive correlation with semen consistency, and mass activity was positively correlated with progressive motility.

Discussion

The current study aimed at evaluating the effect of breed and age on body weight, scrotal measurements and semen characteristics of exotic dairy goat breeds raised on extensive systems under tropical conditions. The study demonstrated that breed did not affect the body weight and scrotal measurements. The non-difference between Toggenburg and Saanen bucks body weights was unexpected. The similarity in body

Table 1 Effect of breed on body weight, scrotal measurements and semen characteristics of Saanen and Toggenburg dairy goats

Parameters	Breed	
	Toggenburg (LSM ± SE)	Saanen (LSM ± SE)
Body weight and scrotal measurements		
Body weight (kg)	51.00± 6.31[a]	42.60 ± 6.31[a]
Scrotal circumference (cm)	28.20 ± 0.89[a]	26.60 ± 0.89[a]
Scrotal length (cm)	11.90 ± 0.57[a]	10.80 ± 0.57[a]
Semen characteristics		
Volume (ml)	1.00 ± 0.10[a]	0.97 ± 0.09[a]
Consistency (0–5)	2.94 ± 0.21[a]	1.76 ± 0.19[b]
Mass activity (0–5)	4.02 ± 0.16[a]	3.69 ± 2.87[a]
Progressive motility (%)	79.24 ± 3.51[a]	74.10 ± 2.63[a]
Sperm concentration ($\times 10^9$/ml)	2.87 ± 0.27[a]	1.67 ± 0.24[b]
Live sperm cells (%)	86.24 ± 2.27[a]	87.49 ± 1.94[a]
Normal morphology (%)	91.24 ± 1.04[a]	91.08 ± 0.95[a]

*Means with same superscripts within the same row do not differ significantly at $P > 0.05$

**LSM* least square means

weight found in this study between the two breeds could be attributed to the fact that Toggenburg goats are more adapted to the tropical environment than the Saanen goats. However, previous studies in the temperate areas reported that Saanen are heavier than Toggenburg (Peacock 1996). This, therefore, implies that Saanen dairy goat breeds may not be suitable for extensive production systems in the tropics.

Although factors such as breed, body weight, age and individual animals have been demonstrated to affect scrotal measurements in goats (Kridli et al. 2005), breed effect was not observed in the current study (Table 1). This could be attributed to similar body weights of the two breeds considered in this study. Since testes is part of the body and respond to tissue growth, they would follow the same trend with body weight. This could explain the breed effects observed on scrotal circumference and length (Belibasaki and Kouimtzis 2000; Kridli et al. 2005). The high positive correlation between body weight and scrotal measurements (scrotal circumference and length) obtained in the current study (Table 3) confirms this phenomenon. This study agrees with results reported by Mellado (2016) who reported close scrotal circumference values of 26.5–27 cm and 26.3 cm in Saanen and Toggenburg bucks, respectively. Additionally, another study reported scrotal circumference of 26.54 cm in Saanen bucks (Ahmed et al. 1997). Moreover, it was reported in another study that breed does not influence scrotal circumference and scrotal length in bucks (Gemeda and Workalemahu 2017).

Table 2 Effect of age on body weight, scrotal measurements and semen characteristics of Toggenburg and Saanen dairy goats

Parameters	Age in years	
	1–2 (LSM ± SE)	3–6 (LSM ± SE)
Body weight and scrotal measurements		
Body weight (kg)	35.20 ± 3.27[b]	58.40 ± 3.27[a]
Scrotal circumference (cm)	26.10 ± 0.73[b]	28.70 ± 0.73[a]
Scrotal length (cm)	10.30 ± 0.35[b]	12.40 ± 0.35[a]
Semen characteristics		
Volume (ml)	0.89 ± 0.10[a]	1.08 ± 0.10[a]
Consistency (0–5)	1.97 ± 0.20[b]	2.73 ± 0.20[a]
Mass activity (0–5)	3.60 ± 0.15[b]	4.12 ± 0.16[a]
Progressive motility (%)	72.05 ± 2.73[b]	81.30 ± 2.78[a]
Concentration ($\times 10^9$/ml)	1.85 ± 0.25[b]	2.70 ± 0.26[a]
Live sperm cells (%)	86.58 ± 1.9[a]	86.62 ± 1.94[a]
Normal morphology	90.25 ± 0.99[a]	92.07 ± 1.00[a]

*Means with different superscripts within the same row differ significantly at $P < 0.05$

**LSM* least square means

Table 3 Pearson's product moment correlation coefficients among body weight, scrotal measurements and semen characteristics of Saanen and Toggenburg goats

Parameters	Correlation (*r*)
Scrotal circumference and body weight	0.74*
Testicular length and body weight	0.83**
Scrotal circumference and testicular length	0.96**
Concentration and consistency	0.97**
Mass activity and progressive motility	0.95**
Volume and scrotal circumference	0.07
Volume and testicular length	0.08
Volume and body weight	0.05
Volume and sperm concentration	− 0.44

*Significant

**Highly significant

Out of the seven semen characteristics evaluated in the current study (Table 1), our findings demonstrated that only semen consistency and sperm concentration were affected by breed. Our findings demonstrated that the breed only affected semen consistency and sperm concentration with Toggenburg being superior to Saanen bucks. This may be attributed to the fact that Saanen bucks are more prone to the heat stress than Toggenburg bucks. Heat stress subsequently increases the level of cortisol and reduces testosterone level (Perez-Crespo et al. 2008).

The result of this study on sperm concentration was in disagreement with the previous study reported by Chandler et al. (1988) in the temperate region and Mellado (2016) which reported lower values of sperm concentration in Toggenburg bucks and higher values in Saanen goats. This difference could be attributed to different environments where these studies were conducted. The temperatures in the tropics are very high, and Toggenburg is well adapted to the tropics compared with Saanen (Takahashi 2012). It had been reported that temperature affects the process of spermatogenesis (Marai et al. 2008) and thus reduces the number of spermatozoa (Perez-Crespo et al. 2008). The sperm concentration of Saanen bucks in this study was lower compared with another study reported by Ahmed et al. (1997) in the tropics. This difference could be attributed to higher body weights of bucks, time of buck exposure to the tropical environment and management system in their study.

Age of buck influences the body weight, scrotal circumference and scrotal length (Table 2). The current study found that old bucks had higher body weight, large scrotal circumference and scrotal length than the young bucks. This was indicative of the linear relationship between live body weight, scrotal circumference and age (Siddiqui et al. 2008). The differences in body weight, scrotal circumference and scrotal length between the two age categories are attributed largely due to physiological development (Ajao et al. 2014). These findings corroborate with the previous studies reported by Kridli et al. (2005), Raji et al. (2008) and Ahmad et al. (2011).

However, age of bucks in the current study did not influence semen volume, live sperm cells and normal morphology. These findings are in agreement with the previous study by Tabbaa et al. (2006) who reported that semen volume, sperm live cells and normal morphology were not affected by age of rams. However, mass activity, progressive motility, semen consistency and sperm concentration were affected by age of bucks, where bucks between 1 and 2 years had lower sperm motility, consistency and sperm concentration compared with those bucks between 3 and 6 years of age. This was an indication that these semen characteristics improve with increasing age of bucks. In agreement with the current study, other previous studies indicated that sperm concentration increased with increasing age in bucks (Al-Ghaban et al. 2004; Mahal et al. 2013). Additionally, it was reported that semen motility and sperm concentration increased as the age of rams increase (Benia et al. 2018). The current findings were in disagreement with previous studies which reported that age had no influence on semen consistency, mass activity, progressive motility and sperm concentration (Kridli et al. 2005; Tabbaa et al. 2006). The discrepancies among these studies could be attributed to factors such as age, breed, nutrition and production system.

In terms of correlations, both scrotal circumference and scrotal length were positively correlated significantly with each other and with body weight. This relationship was expected because testes are body parts that respond to tissue growth, which is observed by the improvement of body weight (Kridli et al. 2005). The current study agrees with previous findings by Gemeda and Workalemahu (2017) which reported positive correlation among scrotal circumference, scrotal length and body weight. Semen volume was positively correlated but not significant with scrotal circumference, scrotal length and body weight. This finding corroborates with previous study by Kridli et al. (2005) who reported positive correlation of ejaculate volume with scrotal circumference and scrotal length. Additionally, the semen volume was negatively correlated but not significant with sperm concentration. This was expected because high volume of semen is associated with low semen concentration and vice versa. This is in agreement with previous studies which reported negative correlation between semen volume and sperm concentration (Kridli et al. 2005; Rehman et al. 2016).

Sperm concentration was positively correlated and significant with the semen consistency. This was expected because high semen density is an indicator of high sperm concentration and vice versa. In agreement with the current study, Kridli et al. (2005) reported negative correlation between sperm concentration and semen volume. There was a positive correlation between semen mass activity and progressive motility. This positive correlation was expected because mass activity of semen gives clear indication of how the individual sperm motility will be. This is in agreement with previous studies which found that mass activity was positively correlated with progressive motility of sperm in bucks (Kridli et al. 2005; Lukusa and Lehloenya 2017) and in bulls (Ray and Ghosh 2013).

In conclusion, the current study found that the Toggenburg and Saanen bucks raised under extensive system in the tropics were similar in terms of body weight, scrotal circumference, scrotal length, volume, mass activity, progressive motility, live sperm cells and sperm morphology. The study also found that Toggenburg bucks had higher semen consistency and sperm concentration as compared to Saanen bucks. Therefore, it could be concluded that Toggenburg bucks can produce high number of total spermatozoa and as a result higher semen doses for artificial insemination purposes. Further studies with more number of animals are recommended.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Statement of animal rights The materials and procedures of this study had been approved by Kenya Institute of Primate Research under the permit no. ISERC/10/19 and National Commission of Science and Technology under the permit no. NACOSTI/P/19/76927/28821.

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