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The timing of the commencement of the breeding season in Boer and Rangeland goats raised in the tropics of Queensland, Australia

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Abstract: This study aimed to determine the timing of the onset of the breeding season in Boer and rangeland goats raised in a tropical region of northern Queensland. The experiment was carried out using 25 Boer and 20 rangeland female goats. Boer and rangeland goats were kept on the same pasture in the absence of males and supplemented to provide nutritional requirements above maintenance. Blood samples were collected once weekly from December 2011 to May 2012 and analyzed for concentrations of progesterone. The mean time to first ovulation was found to occur earlier in Boer compared to rangeland goats (64.7 ± 5.0 days vs 87.7 ± 5.6 days, respectively; $P < 0.05$). Differences in survival curves ($P < 0.05$) for the timing of onset of first ovulation between breeds were also detected. Boer goats started ovulating in December (8.3%) and had all ovulated by March while most rangeland goats started ovulating in March (84%) and had all ovulated by the end of April. These results demonstrate that in a tropical region of north Queensland Boer goats commence ovulatory cycles earlier than rangeland goats which may be beneficial if an earlier start to the breeding season is preferred.

Keywords: goat, progesterone, reproduction, seasonality, photoperiod.

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1. Introduction

In Australia there are approximately 4.5 million goats (FAO, 2013), comprising 4.1 million rangeland goats and 400,000 domestically farmed goats (Pople and Froese, 2012). Thus rangeland goats represent more than 90% of goats thought to be present in Australia. Australia is the largest exporter of goat meat worldwide, slaughtering more than 2 million goats and producing 31,700 tonnes of meat in 2013-14 (McRae and Thomas, 2014). While goat meat exports from Australia commenced in 1952 (Restall et al., 1982), the Australian goat industry remains relatively small and little is known about the production and reproduction of goats raised within tropical regions of Queensland, in which 12% of the goat population in Australia is estimated to be located (Pople and Froese, 2012).

A seasonal distribution in breeding activity is common of sheep and goats living outside the tropics. In subtropical and temperate areas, the breeding season is stimulated by a reduction in the hours of daylight (negative photoperiod), with the largest percentage of conceptions occurring in autumn and winter (Fatet et al., 2011). However, in tropical areas, such as northern parts of Queensland where fluctuations in day length are not as extreme as in more southern parts of Australia (Timeanddate, 2014), it is often hypothesized that food availability is the main factor controlling annual sexual activity within sheep and goats maintained in tropical environments (Mellado et al., 1991; Scaramuzzi and Martin, 2008). At present, there is no information available about the timing of the commencement of the breeding season in Boer and rangeland goats raised in the tropics of Queensland. Determining the onset of the breeding season is critical when determining optimal times for commencement of breeding programs in extensively managed goat herds.

Boer goats are regarded as very adaptable under all environmental conditions of Southern Africa, including mediterranean, tropical and subtropical and semi-desert regions (Casey and Van Niekerk, 1988; Greyling, 2000). Rangeland goats in Australia are descended from the first European settlements and subsequent introductions. These goats were commonly kept by householders as a source of milk and were used as draught animals, some of which established permanent populations within sparsely populated areas of Australia (Restall et al., 1982). Rangeland goats can survive long dry periods, in areas where average annual rainfall ranges from 150 mm to 450 mm and temperatures exceed 40° Celsius in summer (Restall et al., 1982; Thompson et al., 2002). Rangeland goats have therefore adapted over the past 200 years in Australia to the prevailing climatic conditions which could have altered their annual reproductive cycle in comparison to other breeds of goats and fostered natural selection for survival rather than reproductive traits.

Knowledge of the timing of the commencement of the breeding season in Boer and rangeland goats raised within northern Queensland will provide information on when interventions, such as strategic nutritional supplementation and/or hormonal treatments should be applied. The aim of this study was, therefore, to determine the timing of the onset of the breeding season in Boer and rangeland goats raised in the tropics of Queensland, Australia.

2. Material and Methods

2.1 Location, animals and evaluation period

This experiment was carried out at James Cook University, Townsville (19°19'30" S; 146°45'44" E) which is located within a tropical region in Queensland. The experiment was conducted between December 2011 and May 2012, during what was estimated to be the transition from the non-breeding season to the breeding season for goats. A total of 25 Boer and 20 rangeland nulliparous, anoestrous does, were enrolled in the study. In November, every goat was classified as being in anoestrous when no corpora lutea were observed in the ovaries when examined twice 14 days apart using transrectal ultrasonography. At the start of the experiment, the mean (± SEM) age and body weights of the does were 1.5 ± 0.1 years and 43.8 ± 0.9 kg for Boer goats, and 1.4 ± 0.2 years and 35.6 ± 1.0 kg for rangeland goats, respectively. Experimental procedures for the study were approved by the James Cook University Animal Ethics Committee (approval number: A1695).

2.2 Animal management

Female Boer and rangeland goats were maintained on the same pasture in the absence of male goats. Does were supplemented daily with a base ration consisting of lucerne hay and had *ad libitum* access to a pasture of annual ryegrass (*Lolium multiflorum)* in order to provide nutritional requirements above maintenance (7.6 MJ ME/day) for a goat weighing 40 kg (NRC, 2007). The body weights of all animals were monitored every two weeks from November 2011 to May 2012.

2.3 Blood samples and Progesterone assays

Blood samples were collected once weekly (weeks 0 to 18) from the jugular vein using evacuated tubes (BD Vacutainer®, Plymouth, UK) containing lithium heparin. Samples were stored on ice then centrifuged (2500 g for 15 minutes) within two hours of collection. Plasma was then isolated and frozen (-20°C) until the time of assay. The onset of the breeding season was recorded when concentrations of progesterone were determined to be greater than 1 ng/mL in two successive blood samples collected one week apart. The mean time to first ovulation was defined as the interval between the day that goats were first classified as being in anoestrus (Day 0) and the first day when concentration of progesterone exceeded 1 ng/mL (Thimonier, 2000).

Concentrations of progesterone in plasma were measured using a competitive binding enzyme-linked immunosorbent assay (Access Progesterone 33550, Beckman Coulter Australia Pty Ltd, Lane Cove, NSW). The sensitivity of the assay was 0.10 ng/mL. The intra-assay coefficients of variation for low (0.62 ng/mL) and high (5.81 ng/mL) controls were 9.5% and 6.8%, respectively. The corresponding inter-assay coefficients of variation were 17.3% and 14.5%. The ratios for observed/expected values for dilution parallelism using the ELISA assay was assessed using nine serial dilutions of three plasma samples collected from goats in which a CL was observed between days 12 and 15 of oestrous cycle. The average (mean ± SEM) of the observed/expected ratios (efficacy) was 110 ± 2.6%.

2.5 Statistical analyses

Statistical analyses were conducted using the statistical software package IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp. Armonk, NY, 2013). Repeated measures analysis of variance was used to compare the variation in body weight between Boer and rangeland goats. The distribution of the timing of the first ovulation (P4 >1ng/mL) between breeds was determined with the log-rank test (Mantel-Cox), using Kaplan-Meier survival curves. A multivariate Cox proportional model was used to analyse the effect of the initial body weight, breed and their interaction on the interval to first ovulation. In addition, ANOVA was used to determine the difference in the mean interval in days to the first ovulation between breeds and Levene's test was used to assess homogeneity of variance in the mean interval to the onset of first ovulation. The proportion of goats ovulating every month was compared with a Chi-square test. Results are presented as mean ± SEM and differences were considered significant when $P < 0.05$.

3. Results

The mean time to first ovulation was significantly less in Boer goats compared to rangeland goats (64.7 ± 5.0 days vs. 87.7 ± 5.6 days, respectively; P = 0.004). In addition, the variability for the onset of the first ovulation was greater in Boer goats than in rangeland goats (P = 0.010; Fig. 1). Eight percent of Boer goats started ovulating in December, two months before any rangeland goats had started ovulating. Most ovulations in rangeland goats were detected in March (84%), (Fig. 1).

The difference between breeds for the distribution of the timing of the first ovulation was also supported by differences in the Kaplan-Meier survival curves between breeds (P = 0.038). The timing of first ovulation in Boer goats occurred gradually over the period of 18 weeks, in contrast to rangeland goats, in which the timing of first ovulation happened suddenly between weeks 10 and 12 (Fig. 2).

Analysis of body weights between the two breeds over time indicated that there were differences between breeds (P = 0.001). The mean weights of Boer and rangeland goats throughout the study were 43.0 ± 0.9 and 36.3 ± 0.9, respectively. While the initial body weight of both breeds was similar to their final body weight, the magnitude of the difference in body weight between breeds varied over time although Boer goats were always at least 5.6 kg on average heavier than rangeland goats throughout the study. Body weight was included in the model as a covariate, but the Cox regression analysis did not show any effect (P = 0.537) of the body weight on the time to first ovulation.

4. Discussions

Determining the onset of the breeding season is critical when determining optimal times for commencement of breeding programs in extensively managed goat herds in order to condense the kidding season and improve annual production (Freitas et al., 2004). In this study, when we compared the onset of first ovulation in anoestrous does, we found a different pattern in the timing of onset and an earlier mean time interval to a first ovulation in Boer goats.

The results from this study indicate that rangeland goats in a tropical environment located closer to the equator started ovulating earlier compared with what has previously been reported for the same breed located in a more southern location of Australia. For instance, in a study conducted in north-eastern New South Wales (29ºS, 154ºE), Restall (1992) observed that rangeland does, separated from males, began to ovulate between April-May, with 30% of does ovulating during this period. In addition, the highest incidence of ovulatory activity in rangeland does was detected between June-July, with 60% of does ovulating during that period. In this study, over 84% of rangeland does had ovulated by March and 100% by April (Fig. 1). The difference in the timing of the commencement in the breeding season between different studies is likely to be due to differences in day length (Fatet et al., 2011). In addition, other factors like temperature, humidity, rainfall, food supply, body condition and the method to detect ovulation might be affecting the timing of the first ovulation between experimental sites (Chemineau et al., 1992; Duarte et al., 2008).

Zarazaga et al. (2005) studied the effect of nutrition on the seasonal pattern of sexual activity in Payoya goats kept under a natural photoperiod (37º15'N) for 20 months. They reported that the duration of breeding season was increased by about one month when does received 1.5 times maintenance compared with those that received only a maintenance diet. Thus differences in nutritional supplementation or variations in feed intakes between studies could also contribute to differences in the pattern of onset of first ovulation observed in goats. On the other hand, according to Duarte et al. (2008) reproductive seasonality in goats in a subtropical environment (26º23'N) persisted independently of food availability and they reported that photoperiod is the key factor regulating seasonality in subtropical latitudes. In this study, both breeds were supplemented to above maintenance requirements and still varied in their interval to first ovulation. The results, therefore, suggest that while the onset of cyclicity may be affected by factors such as body condition, food availability and the presence or absence of male animals, genetic factors interacting with photoperiod can significantly modulate the onset of the breeding season in goats within subtropical environments (Mellado et al., 1991; Chemineau et al., 1992; Duarte et al., 2008).

The reasons why Boer goats started the breeding season earlier than rangeland goats are unclear from the results of this study. However, possible reasons may be suggested. First, Boer goats have been selected over a long period as a precocious breed for red meat production with greater selection pressure for reproductive traits (Casey and Van Niekerk, 1988; Malan, 2000), while rangeland goats have existed mainly in the wild with only natural selection for a reproductive capacity that favours their survival within a rangeland environment. Second, even though goats within each breed were of similar age groups, the heavier weight of Boer goats compared to the rangeland goats may have encouraged the resumption of the ovarian activity earlier in Boer goats, although this is not supported by our finding that body weight was not significantly associated with the interval to first ovulation with survival analysis. The results of this study agree with previous studies with Boer goats, in which the body weight could not be correlated to the annual oestrous activity (Greyling, 2000). The same author reported that sexual activity in Boer goats and daylight length was recorded to have a significant negative correlation ($r^2 = -0.654$). This may suggest that genetic sensitivity to photoperiod is a more important driver of the timing of the onset of ovulation than absolute body weight when nutritional requirements are being met. Finally, we also speculate that the difference in temperament between Boer and rangeland goats may contribute to the longer timing for the onset of the breeding season. In this study, we observed a greater flight zone for the rangeland goats compared to the Boer goats. The greater flight zone and other stressors are associated with activation of the hypothalamus-pituitary-adrenal axis to increase concentrations of cortisol in goats (Kannan et al., 2000). Furthermore, the circadian rhythm also influences cortisol production and is associated with changes in photoperiod (Alila-Johnansson et al., 2003). Although unmeasured in this study, it is possible that concentrations of cortisol may have contributed to the delay in the onset of the breeding season in rangeland goats.

Differences in seasonality and onset of puberty between breeds of goats have been reported in the literature, which highlights the influence of genotype on reproductive cyclicity in goats. For instance, Amoah et al. (1996) reported that Nubian and Pygmy female goats (breeds of tropical ancestry) when raised in temperate region have an extended breeding season when compared to Saanen, Toggenburg and American Alpine does. This could be due to reduced sensitivity of Nubian and Pygmy goats to changes in photoperiod during the year. In tropical regions, Saanen female kids achieved puberty earlier than Anglo-Nubian goats when raised in the same environment (Freitas et al., 2004). These same authors reported that the precocity of Saanen goats was due to a faster growth rate in Saanen than Anglo-Nubian goats, which suggests that nutrition may interact with photoperiod to influence reproductive function. In this study, goats remained relatively stable in body weight and were fed with a diet which provided above maintenance nutritional requirements.

Different responses between breeds to photoperiod could be due to different genetic abilities to secrete melatonin or differences in signal transmission within the brain or differences in responsiveness to circulating concentrations of oestradiol (Rosa and Bryant, 2003). Photoperiodic control of reproductive patterns is mediated through secretion of melatonin by the pineal gland during darkness, which in turn influences the secretion of GnRH and hypothalamic-pituitary-gonadal feedback (Chemineau et al., 1992; Fatet et al., 2011). As Boer and rangeland goats have different genetic backgrounds, it could be that they have different abilities to translate the signal of melatonin in the pituitary gland and hypothalamus. The seasonality of reproduction in sheep is primarily due to changes in the responsiveness of the hypothalamus to the negative feedback of oestradiol, which in turn is dictated by variations in the length of the daily photoperiod (Rosa and Bryant, 2003). Reproductive function in male sheep is also less responsive than in females to changes in photoperiod and this has in part been attributed to males having a lower sensitivity to oestradiol than females (Lubbers and Jackson, 1993). According to the same authors, this is explained by the finding of lower concentrations of mRNA oestrogen receptors in the hypothalamus of males than in females, which could explain the greater suppression of LH secretion in females than in male sheep during the non-breeding season (Lubbers and Jackson 1993).

Similarly, Boer goats may have a lower sensitivity to oestradiol than rangeland goats and, as a consequence, concentrations of LH are greater in Boer goats than rangeland goats during transition from anoestrous to the breeding season. In summary, the earlier onset to the breeding season in Boer goats than rangeland goats could be explained by a combination of different responsiveness to photoperiod and different sensitivity to oestradiol in the hypothalamus.

5. Conclusion

Goats fed above nutritional maintenance requirements, in a tropical region of Australia commenced their breeding season from December to April, although the pattern of onset of ovulation was affected by breed. In this study, onset to the first ovulation, determined by the concentrations of progesterone, in Boer goats was more precocious than rangeland goats, which indicates that there are likely genetically driven differences in sensitivity to photoperiod between these breeds. Managing the timing of the start of the breeding season for goats on commercial farms in tropical regions should take into consideration not only the seasonality of reproduction, but also potential differences between genotypes in the onset of the breeding season. In addition, for an earlier start of the breeding programs, we sugest that Boer goats may be a better commercial option than rangeland goats.

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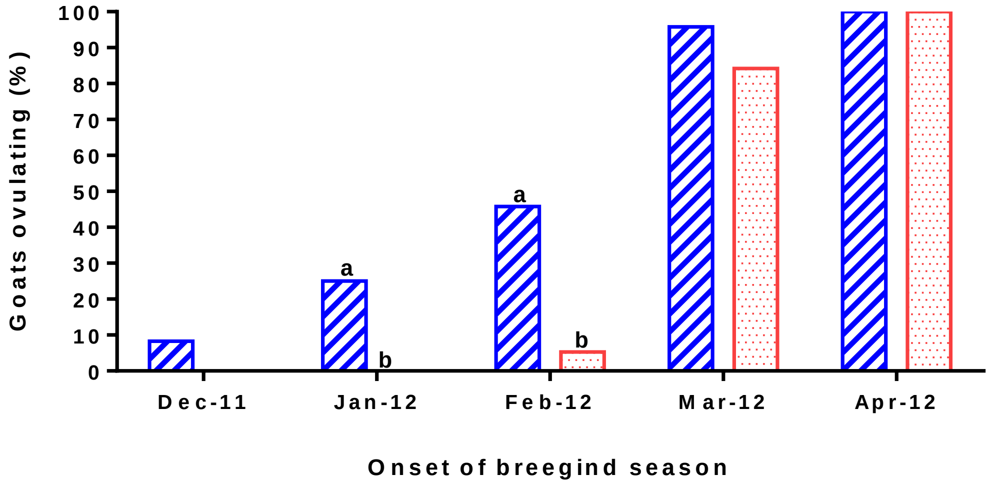

Fig. 1. Cumulative percentage of Boer () and rangeland () goats ovulating between December and April (ab: within months differ; $P < 0.05$)

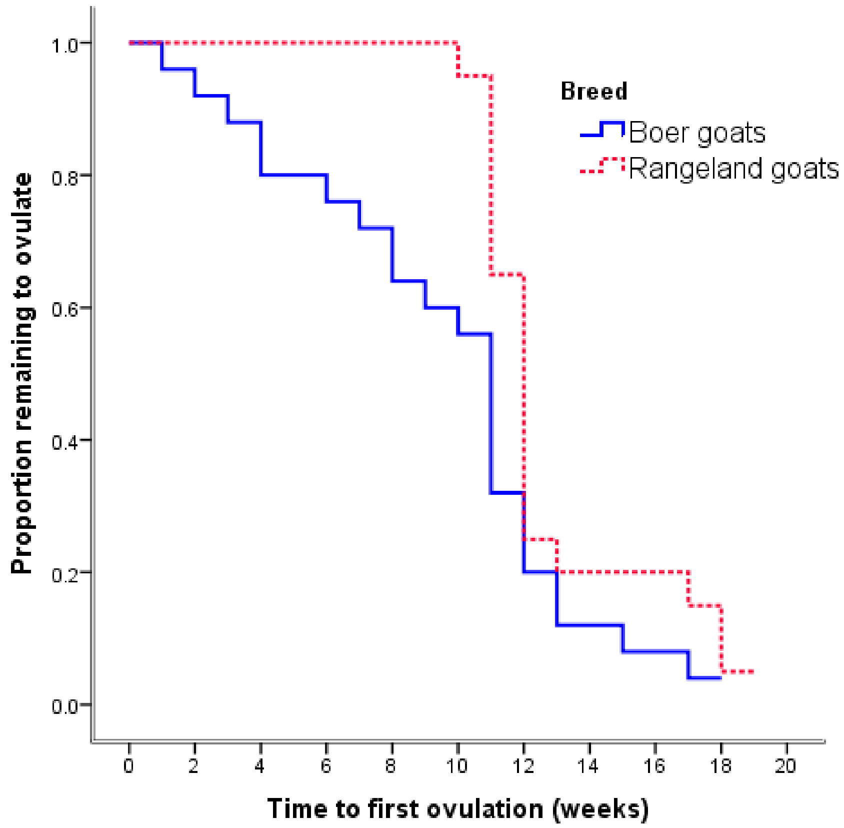

Fig. 2. Kaplan-Meier survival plot of the onset of the first ovulation in Boer and rangeland goats.