Role of body condition score and body weight in the control of seasonal reproduction in Blanca Andaluza goats

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Abstract

The reproductive activity of 84 female Blanca Andaluza goats was monitored over 17 months to determine the role of body condition score (BCS) and body weight (BW) in its control. Following a 3x2 factorial experimental design, the animals were allocated to three groups: low BCS (≤2.50, n=24), medium BCS (BCS=2.75-3.00, n=31) and high BCS (≥3.25, n=29). The same animals, irrespective of their BCS group membership, were also divided into two groups depending on their BW: low BW (≤40 kg, n=44) and high BW (>40 kg, n=40). Oestrus was tested daily using vasectomized males. The ovulation rate was assessed by transrectal ultrasonography after the identification of oestrus. Ovulatory activity was determined by monitoring the plasma progesterone concentration weekly. BCS and BW were recorded once a week and their nutrition adjusted to maintain the initial differences between the groups. Both BCS and BW had a significant (at least P<0.05) influence on the onset, the end, and the duration of the breeding season, with longer periods of reproductive activity recorded in does with a BCS of ≥2.75 and BW of >40kg. No significant interaction between these variables was observed. Some 11.7% of the does in the groups with animals of BCS≥2.75 showed ovulatory activity during seasonal anoestrus. None of the does with a BCS of ≤2.5 showed this. The ovulation rate of the first and last oestrous was modified by BW (P<0.01). These results demonstrate that Blanca Andaluza goats show marked reproductive seasonality that is clearly and independently modulated by BCS and BW.

Key words: Female goat, Breeding season, Nutrition, Progesterone, Oestrous.

1. Introduction

The Blanca Andaluza breed of goat, which is native to Spain and adapted to Mediterranean environmental conditions, is endangered according to the Official Catalogue of Spanish Livestock Breeds (R.D 2129/2008). Steps should therefore be taken to ensure its preservation. The raising of these goats provides a representative example of a grazing-associated goat meat production system. Kids are slaughtered when their body weight reaches 8-9 kg (De la Vega et al., 2013). The majority of farms that produce Blanca Andaluza goats are found in Andalusia (southern Spain), usually in areas of difficult terrain and poor soils, and where there are climate-induced fluctuations in food availability. Compared to other Spanish goat breeds, Blanca Andaluza reproductive physiology (i.e., seasonality of reproduction, puberty, time of ovulation) has been very little studied, yet such knowledge is vital if the continuity of the breed is to be guaranteed.

Seasonality of reproduction, which directly affects milk and meat production, is a major problem in goat production. Seasonality is the consequence of changes in the responsiveness of the neuroendocrine system to the inhibitory action of oestradiol (Zarazaga et al., 2005). Indeed, oestradiol's negative feedback stimulation of gonadotrophin secretion, and consequently its effect on ovulatory activity, varies dramatically between the breeding and anoestrus seasons (Karsch et al., 1984). The photoperiod provides the main cue that controls this seasonal pattern (Chemineau et al., 1988), with long days inhibiting and short days stimulating sexual activity (Zarazaga et al., 2011a, b, c). This seasonal reproductive pattern ensures that parturition and lactation coincides with the period of greatest feed availability and most favorable temperatures (usually spring) (Martin et al., 2004). The time of onset and length of the breeding period are dependent on different environmental and physiological factors such as latitude, climate, food availability, breed, and the breeding system followed (Fatet et al., 2011).

Nutrition and the effect of body condition score (BCS) and body weight (BW) can influence reproductive activity in different goat breeds. Zarazaga et al. (2005) reported the expression of seasonality to be modified by the nutritional environment, with a longer breeding period in goats enjoying better nutrition that led to higher BCS and BW scores. Estrada-Cortés et al. (2009) concluded the length of the anovulatory period to be partially modulated by the nutritional energy status of Mexican Creole does maintained at tropical latitudes. In the Mediterranean area, the majority of goats are raised in extensive or semi-extensive systems, and production is subject to seasonal variations in food availability. It is often suggested that nutrition, and therefore BW and BCS is responsible for the seasonal reproductive pattern. Reproductive performance commonly correlates with changes in BW, and severe BW loss is usually accompanied by anoestrus (Richards et al., 1989). Moreover, BCS is directly related to nutrition. De Santiago-Miramontes et al. (2009) concluded that does in poorer body condition have a shorter breeding season, more abnormal oestrous cycles, and fewer ovulations than does in good body condition. However, none of the previous investigations could determine whether the influence of BCS was independent of that of BW since these variables were always associated with one another.

The aim of the present work was to describe the seasonal pattern of the Blanca Andaluza goat breed and the influence of BCS and BW as modulators of reproductive activity, and to determine whether there is any additive or compensatory interaction between them.

2. Methods and Materials

2.1. Study conditions

The present study was performed in accordance with the Spanish Animal Protection Policy described in *Real Decreto 53/2013*, which conforms to European Union Directive 2010/63 regarding the protection of animals used in scientific experiments. It was conducted at the experimental farm of the University of Huelva (latitude 37º 20'N longitude 6º 54' W), which meets the requirements of the European Community Commission for Scientific Procedure Establishments (1986).

2.2. Animals

The animals used were 84 adult (1.5-2 years old at the onset of the experiment), non-pregnant Blanca Andaluza does. The experiment started on 20th January and finished on 26th June of the following year. A 3x2 factorial experimental design was followed with three BCS groups and two BW groups. The does were first divided on the basis of their BCS into three groups based on a 1-5 scale (1=emaciated and 5=extremely fat, with increments of 0.25, Hervieu et al., 1991): BCS≤2.50 (n=24), BCS=2.75-3.00 (n=31), and BCS≥3.25 (n=29). Then, irrespective of their BCS group membership, they were also divided into a low BW group (BW≤40 kg, n=44) and a high BW group (BW>40 kg, n=40). Tables 1a, 1b and 1c show the mean BW and BCS at the beginning of the experiment for each group.

The diets were designed to have no effect on normal protein intake. The quantity of the diet offered was adjusted to the mean BW of the animals in each group according to INRA standards (Morand-Fehr and Sauvant, 1988) in order to maintain the initial differences in BW and BCS between the groups. Concentrate was offered individually once per day, and barley straw distributed to each group as a whole. All animals had free access to water and mineral blocks containing trace elements and vitamins. The concentrate was a commercial mixture of maize (26.3%), beans (20.0%), oats (14.1%), cotton-seed (13.7%), peas (13.4%), lupin (7.3%), barley (0.2%), wheat (0.2%), sunflower seeds (0.2%) and a mineral-vitamin complement (4.6%). The nutritional values of the concentrate was 0.93 milk fodder units (UFL) and 76 g of digestible protein/kg of dry matter, while the barley straw provided 0.37 UFL and 25 g of digestible protein/kg dry matter.

2.3. Management and measurements

BW and BCS (Hervieu *et al*., 1991) were recorded weekly for all animals. BCS was always scored by the same handler.

Oestrous activity was tested daily using vasectomized adult males fitted with marking harnesses. Oestrous activity was recorded by direct visual observation every day of the marks left by the harnesses (Walkden-Brown et al., 1993).

The occurrence of ovulation and the ovulation rate were assessed by the presence and number of corpora lutea observed in each female by transrectal ultrasonography conducted 10 ± 2 days after the detection of oestrus (Simoes et al., 2005). Transrectal ultrasonography was performed using an Aloka SSD-500 apparatus connected to a 7.5 MHz linear probe.

To determine the percentage of silent ovulations before the first behavioural oestrus, and to confirm ovulatory activity, blood samples were collected weekly from each animal by jugular venipuncture and assayed for progesterone. Immediately after collection, samples were centrifuged and the plasma stored at -20ºC until assay. The percentage of does expressing oestrus with or without ovulations, or ovulation in the absence of behavioural oestrus, was confirmed from the plasma progesterone concentrations, which were determined using a commercial enzyme linked immunoassay (ELISA) kit (Ridgeway Science Ltd., Gloucester, UK) according to the manufacturer's instructions (Madgwick et al., 2005). The mean intra-assay and inter-assay coefficients of variation were 8.5% and 12.2% respectively. The sensitivity of the assay was 0.1 ng/mL. Females with progesterone concentrations of ≥0.5 ng/mL were considered to have had ovulations (Chemineau et al., 1984; Zarazaga et al., 2009).

2.4. Definitions of reproductive activity

The mean duration of oestrus cyclicity and the ovulatory season were respectively defined as the number of days between the first and the last detected oestrus, and the first and the last ovulation, in the same breeding season (Chemineau et al., 1992).

Ovulatory activity was confirmed when two or three consecutive plasma samples had progesterone concentrations above baseline (0.5 ng/mL) with subsequent cyclicity. For each goat, the date of the last plasma progesterone value below baseline that was followed by the first extended cyclic pattern was taken as the onset of ovulatory activity. Cessation of ovulatory activity was considered to have occurred when four or more consecutive plasma samples had concentrations below baseline. The date of the last plasma progesterone value below baseline at the completion of the last extended cyclic progesterone pattern was taken as the end of ovulatory activity.

Patterns of sexual activity observed during the breeding season were defined as: (i) oestrus cycle: when detected oestrus behaviour was accompanied by an increase in serum progesterone levels above 0.5 ng/mL; (ii) silent ovulation: when an increase in serum progesterone levels above 0.5 ng/mL in at least two consecutive samples occurred with no preceding oestrus behaviour; and (iii) a percentage of goats showing oestrus during each month.

2.5. Statistical analyses

ANOVA for repeated measures was performed to study the effect of the initial BCS and BW on changes in these same variables. The mean (±S.E.M.) onset times of reproductive activity and seasonal anoestrus, as determined by oestrus cyclicity and/or ovulatory activity, as well as the duration of reproductive activity, were calculated. ANOVA was used to assess the effect of BCS and BW on each studied reproductive variable. When differences between groups were observed, the Tukey test was performed. The monthly percentage of females in each group showing ovulation or oestrous cycles was compared using the χ^2 test.

The ovulation rate was calculated at each detected oestrus and the means (±S.E.M.) for the different groups compared using the Mann-Whitney U test.

Significance was set at $P<0.05$. All analyses were performed using the SPSS package (Statistical Package for the Social Sciences, 2008).

3. Results

3.1. Effect of initial body condition score and body weight on changes in these variables

No interaction between BCS and BW was observed in terms of the change in these variables over the experimental period. Figure 1 shows the change in BCS for the three BCS and two BW groups.

As expected, the differences in BCS between the does in the different BCS groups at the beginning of the experiment were maintained until the end (their nutrition was controlled to ensure this) (Fig. 1, Table 1a, 1b, 1c) ($P<0.05$), without affecting their

BW (Table 1a). Similarly, the differences in BW between the does in the different BW groups at the beginning of the experiment were maintained until the end, and had no effect on BCS (Table 1b) ($P<0.05$).

3.2. Effect of body condition score and body weight on reproductive variables.

No interaction between BCS and BW was observed with respect to any of the studied reproductive variables. Tables 2 and 3 show the mean dates for the onset of the ovulatory/oestrous and anovulatory/anoestrous seasons, as well as the duration of the breeding season (determined by progesterone concentrations or by oestrous).

However, BCS and BW had significant (at least $P<0.05$), independent effects on all the reproductive variables studied. The reproductive variables were, in general, better (earlier onset of breeding activity, later end of breeding activity, longer duration of the breeding season) in the females with the higher BCS (≥2.75) groups (at least $P<0.01$), and in females with BW>40 kg (at least $P<0.05$).

Figures 2 and 3 show the monthly mean percentage of does showing reproductive activity (oestrus or ovulatory activity), which varied significantly over time ($P<0.001$). The months of least oestrous activity were May to July (significantly less activity than August to January [$P<0.05$]). Ovulatory activity was greatest from August to February ($P<0.05$ compared to May to July). March to April was a transition period during which around 50% of the females showed ovulatory activity.

The BCS modified the percentage of females that showed reproductive activity over the duration of the experiment. The higher BCS (≥2.75) groups returned the highest percentages of females showing ovulatory activity ($P<0.01$) and oestrous with ovulation ($P<0.01$ compared to the BCS≤2.50 group) (Table 2). Similarly, BW modified the percentage of females that showed reproductive activity over the entire experiment.

The BW>40 kg group returned a higher percentage of females showing ovulatory activity ($P<0.01$) and oestrous accompanied with ovulation compared to the BW≤40 kg group ($P<0.01$) (Table 3). No interaction between BCS and BW was observed ($P>0.05$).

Seven females showed ovulatory activity (measured by progesterone concentration) over the entire experimental period, and all of these had a BCS of ≥2.75 (i.e., 11.7% of the does with such a BCS). Three of these seven does had a BW of ≤40 kg (10% of all does with low BW) while the other four had a BW of >40 kg (13.3%).

3.3. Effect of BCS and BW on ovulation rate.

Tables 2 and 3 show the mean ovulation rate of the first and last oestrous activity of the breeding season. The ovulation rate of both these oestrous events was modified only by the BW, with a higher ovulation rate in the BW>40 kg females than in the BW≤40 kg females ($P<0.01$).

4. Discussion

The present results reveal that, when maintained under a natural photoperiod, the Blanca Andaluza breed shows reproductive activity between August and April, and anoestrous between May and July. This seasonality is modulated by BCS and BW, although these factors do not interact.

The literature contains reports on goats (De Santiago-Miramontes et al., 2009) and sheep (Forcada et al., 1992) that show an association between poorer body condition and a shorter breeding season, but in both these studies the heavier does also had a better BCS. These studies could not, therefore, differentiate between the effects of BCS and BW. Similarly, in other experiments in goats in which the effect of nutrition on reproductive activity was studied (Zarazaga et al., 2005, 2011a, 2011b, 2011c), the level of nutrition induced differences in BCS and BW, so again their separate effects could not be distinguished. In the present experiment, animals with different BCS were selected, but these were also separated into groups of different BW; this helped differentiate between the effect of these variables on breeding activity over the year. No interaction between BCS and BW was seen with respect to any studied variable, indicating them to act independently of one another. This requires the rejection of the hypothesis that these variables can compensate for one another. Further, no synergistic effect was seen between BCS and BW: the group of females with the highest BCS and BW showed no better reproductive activity than the females with a high BCS but lower BW, or females with medium BCS and high or low BW. The does with a BCS of $\geq$2.75, and those with a BW of >40 kg had a longer breeding period than females with a BCS of $\leq$2.50 or a BW of $\leq$40 ($P<0.01$).

It may be that a lower BCS or a lower BW is perceived by the hypothalamus via a reduction in GnRH secretion (Imakawa et al., 1987; Tanaka et al., 2002). The positive effect of a higher BCS or BW on the duration of the breeding season might therefore be meditated by a leptin signal. Archer et al. (2002) observed higher plasma leptin concentrations in castrated+E_2 male sheep with a higher BCS. Moreover, ewes that show a higher BCS have higher FSH and lower oestradiol concentrations (Viñoles et al., 2005). The reduced oestradiol production in these animals is likely associated with the higher leptin levels shown by those with a high body fat content. Lower oestradiol concentrations might reduce the negative feedback reaching the hypothalamus-pituitary axis, thereby, increasing LH and FSH concentrations and inducing a longer breeding period.

Some of the present females showed ovulatory activity during seasonal anoestrous. In the same latitude as that at which the present experiment was performed, our group, working with Payoya goats (Zarazaga et al., 2005), observed no oestrous or ovulatory activity during seasonal anoestrous. Neither was ovulatory activity seen during seasonal anoestrous by Gómez-Brunet et al. (2003) who worked with Malagueña goats at a similar latitude. Nor did De Santiago-Miramontes et al. (2009) observe any ovulatory or oestrous activity during seasonal anoestrous in Criolla goats at a subtropical latitude. The reason for this difference between Blanca Andaluza goats and these other breeds may lie in their sensitivity to the negative feedback effect of oestradiol during seasonal anoestrous. However, it has been shown that nutrition can modulate breeding activity (Zarazaga et al., 2011a,b,c), which might also explain why the females with permanent ovulatory activity were always from the groups with BCS ≥2.75, independent of their BW. This indicates that the reduction of hypothalamus-pituitary axis sensitivity to the negative feedback of oestradiol is sufficient to stimulate reproductive activity.

A large number of ovulations unaccompanied by oestrus, especially during seasonal anoestrus (4.5-38.0% in the cycles of May and June) was recorded. Identical findings have been reported in certain breeds of sheep with reduced seasonality (Thimonier and Mauleon, 1969; Wheeler and Land, 1977; Avdi et al., 1988; Forcada et al., 1992; Arroyo et al., 2007), but not in goats living at similar or even lower latitudes (Rivera et al., 2003; Zarazaga et al., 2005; De Santiago-Miramontes et al., 2009; Chentouf et al., 2011). However, similar results were reported by Chemineau et al. (2004) for Creole goats under simulated tropical photoperiod conditions. These silent ovulations were associated with seasonal variations in sensitivity to oestradiol (Karsch et al., 1978; Webster and Haresign, 1983). In the present study, the higher percentages of oestrus and ovulatory cyclicity recorded in does with higher BCS or BW show that oestrus reactivation can be modulated by nutritional status, as suggested by other authors (I'Anson and Legan, 1988; Forcada et al., 1992; Zarazaga et al., 2011a, b, c),.

In Blanca Andaluza goats, neither the ovulation rate during the first nor the last oestrous of the breeding season was modified by BCS, although it was affected by BW. This finding is similar to that described by Zarazaga et al. (2005) in Payoya goats. It may be that the animals with a BW of >40 kg, independent of their BCS, had a higher body mass index, and as a consequence showed better body development, a greater capacity to accommodate a higher pregnancy rate, and perhaps even better development of the hypothalamus-pituitary axis. Indeed, the present results seem to indicate that even a BCS of ≤2.50 is sufficient for positive reproductive capacity if the BW is adequate (around 45 kg, i.e., the mean of the group with BCS ≤2.50).

In conclusion, the results of the present experiment support the hypothesis that Blanca Andaluza does show a period of reproductive activity from August to February-March depending on the BCS and BW, the influence of both being entirely independent. Females of this breed may need at least a BCS of 2.75 and a BW of 40 kg for seasonal anoestrous to be reduced. Some does show ovulatory activity during seasonal anoestrous. The ovulation rate associated with the first and last oestrus is greater in does with a BW of >40 kg.

Conflicts of interest

None of the authors of this paper has a financial or personal relationship with other persons or organisations that might inappropriately influence or bias its content.

Acknowledgments

The authors thank the *Asociación Nacional de Criadores de Cabra Blanca Andaluza* (ABLANSE) for supplying the animals used in this work. This study was funded by Grant RZ2010-00001-00-00 from the I.N.I.A-C.I.C.Y.T (Spain).

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Figure 1: Change in body weight (BW [kg], filled symbols) and body condition score (BCS, blank symbols) over the experimental period in female Blanca Andaluza goats with BCS≤2.50 (◊), with BCS=2.75-3.00 (□), with BCS>3.00 (△), with BW≤40 kg (♦) and with BW>40 kg (■).

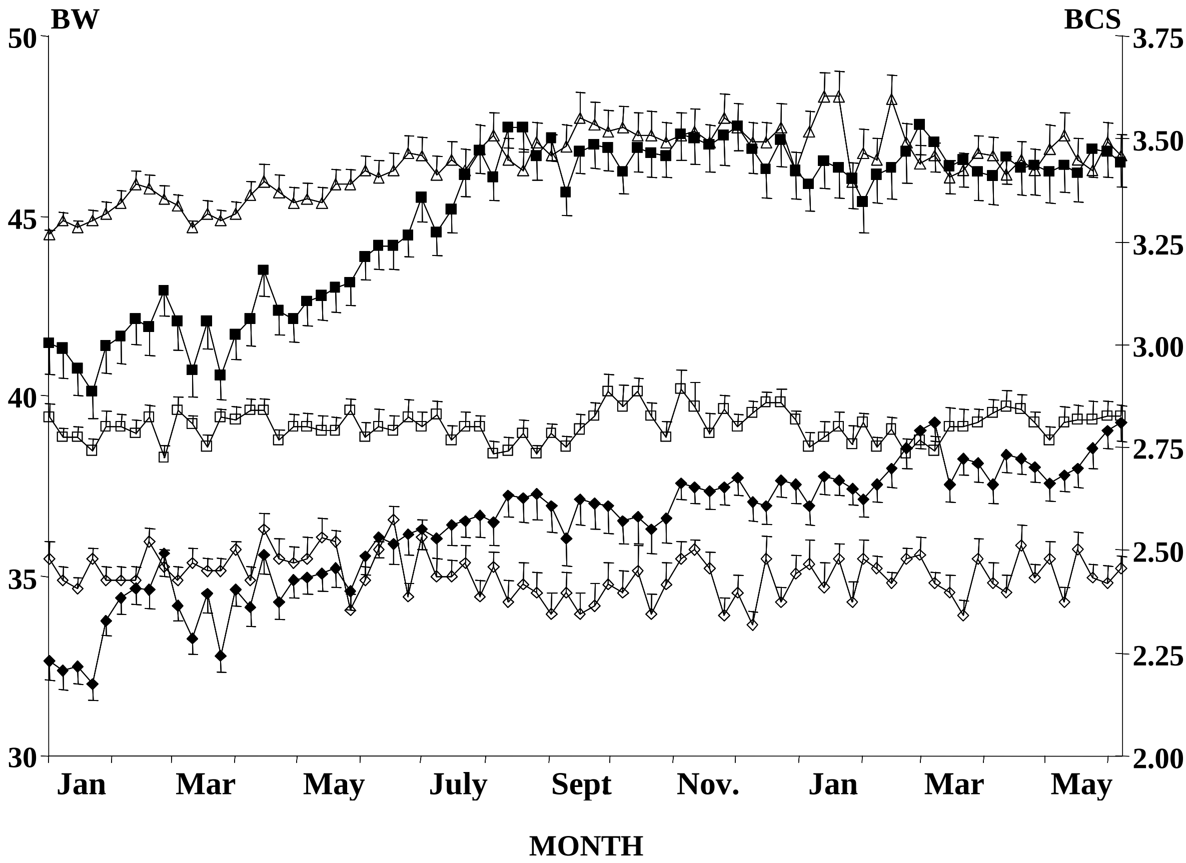

Figure 2: Monthly percentage of does showing oestrous (lines) or ovulation (barred symbols) depending on their body condition score (top panel: BCS≤2.50,▨,♦; BCS=2.75-3.00, ▩, ■; and BCS≥3.25, □, ▲), and on their body weight (bottom panel, BW≤40 kg,▨, ♦ or BW>40 kg,□, ■).

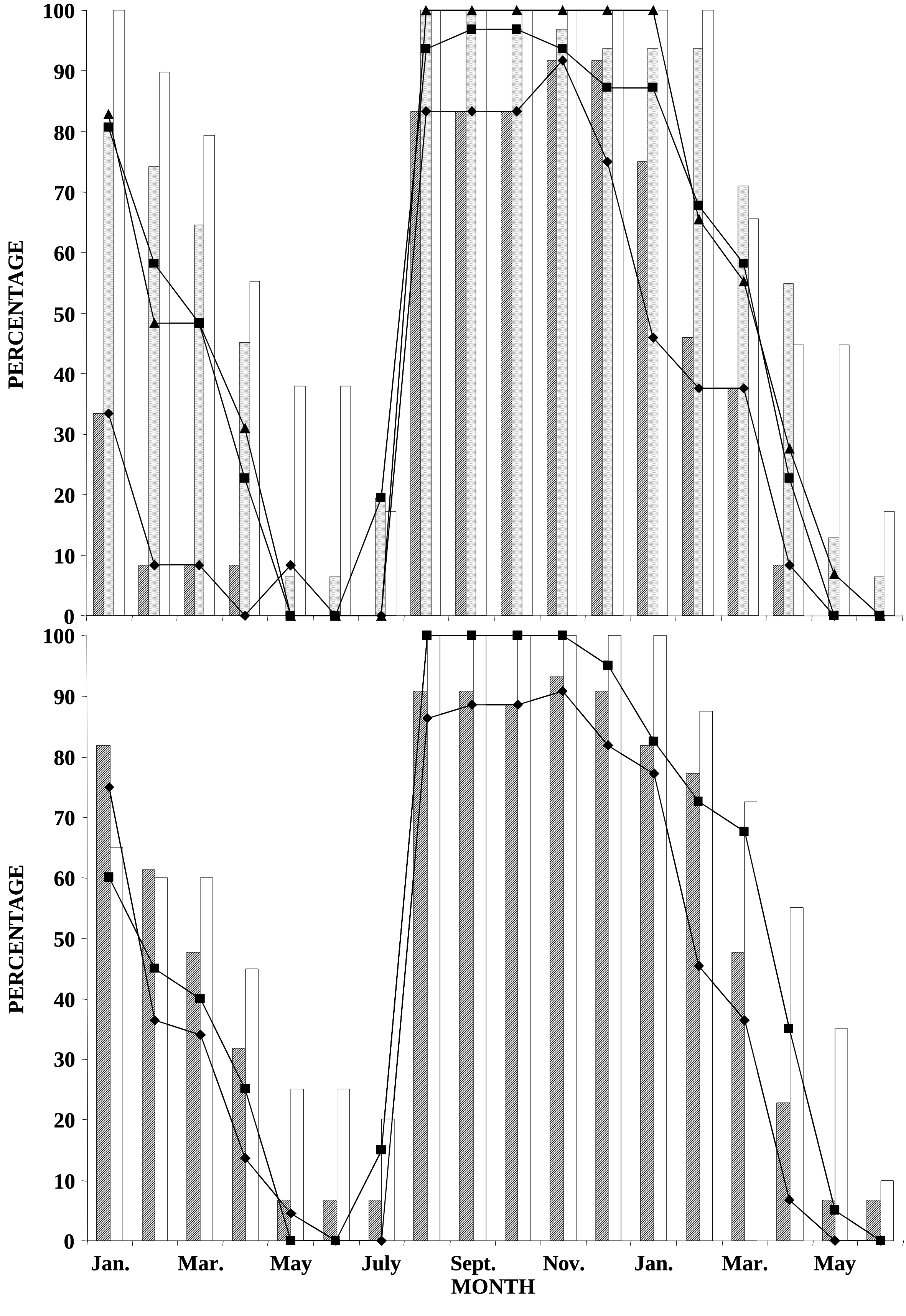

Table 1a. Mean ± S.E.M body condition score (BCS) and body weight (BW) at the onset and at the end of the experiment for each group of Blanca Andaluza does, depending on their initial BCS.

BCS groups	≤2.50	2.75-3.00	≥3.25
N	24	31	29
Initial BCS	2.48±0.04aA	2.82±0.03bA	3.27±0.01cA
Final BCS	2.45±0.03aA	2.83±0.03bA	3.46±0.05cB
Initial BW	37.2±1.6aA	36.7±1.1aA	36.6±1.0aA
Final BW	40.9±1.0aA	43.0±0.9aB	44.1±1.1aB

Different letters in the same row are significantly different (a,b: at least P<0.05), as are different letters in the same column (A,B: at least P<0.05).

Table 1b. Mean ± S.E.M of the body weight (BW) and body condition score (BCS) at the onset and the end of the experiment for each group of Blanca Andaluza does, depending on their initial BW.

BW groups	BW≤40	BW>40
N	44	40
Initial BW	32.6±0.5aA	41.5±0.9bA
Final BW	39.3±0.5aB	46.5±0.7bB
Initial BCS	2.87±0.05aA	2.89±0.06aA
Final BCS	2.94±0.08aA	2.96±0.07aA

Different letters in the same row are significantly different (a,b: at least P<0.05), as are different letters in the same column (A,B: at least P<0.05).

Table 1c. Mean ± S.E.M of the body condition score (BCS) and body weight (BW), at the onset and the end of the experiment, of each group of Blanca Andaluza does depending on their initial BCS and BW.

BCS subgroups	≤2.50		2.75-3.00		≥3.25	
BW subgroups	BW≤40 kg	BW>40 kg	BW≤40 kg	BW>40 kg	BW≤40 kg	BW>40 kg
N	14	10	15	16	15	14
Initial BCS	2.46±0.04a	2.50±0.08a	2.87±0.05b	2.78±0.04b	3.25±0.00c	3.29±0.02c
Final BCS	2.42±0.08a	2.50±0.00a	2.84±0.05b	2.81±0.03b	3.45±0.08c	3.46±0.08c
Initial BW	31.6±1.2a	45.0±1.3b	33.0±1.0a	40.3±1.5b	33.2±0.3a	40.3±1.4b
Final BW	38.0±0.5a	44.5±1.5b	38.4±0.9a	47.1±0.5b	39.1±1.1a	47.3±1.5b

Means with different letters at the same row are significantly different (a, b, c: P<0.01).

Table 2. Mean ± S.E.M of the different reproductive variables studied depending on initial body condition score (BCS).

BCS subgroups	≤2.50	2.75-3.00	≥3.25
N	24	31	29
Onset of ovarian activity	6 Sept ± 4.6a	13 August ± 2.9b	16 August ± 0.8b
Onset of breeding season (ovulation and oestrous)	30 Aug ± 4.9a	12 August ± 3.4b	14 August ± 1.2b
End of the breeding season as determined by ovarian activity	14 Feb ± 9.3a	19 March ± 7.3b	21 March ± 7.8b
End of the breeding season as determined by oestrous and ovulation	20 Jan ± 10.9a	19 Feb ± 9.3ab	27 Feb ± 8.7b
Duration of the breeding season as determined by the presence of progesterone (days)	161.1 ± 12.1a	216.2 ± 8.5b	217.2 ± 7.8b
Duration of the breeding season as determined by the presence of oestrous (days)	143.6 ± 14.0a	188.4 ± 10.9b	198.4 ± 8.3b
Ovulation rate at first oestrous	1.55 ± 0.18a	1.48 ± 0.11a	1.62 ± 0.11a
Ovulation rate at last oestrous	1.23 ± 0.09a	1.50 ± 0.09a	1.50 ± 0.10a
Mean nº females showing ovulatory activity (%)	37%A	62%B	70%B
Mean nº females showing oestrous and ovulatory activity (%)	34%A	52%B	54%B

Different letters in the same row are significantly different (a,b: $P<0.05$; A,B: at least $P<0.01$).

Table 3. Mean ± S.E.M of the different reproductive variables studied depending on initial body weight (BW).

BW subgroups	BW≤40	BW>40
N	44	40
Onset of ovarian activity	25 August ± 2.9a	16 August ± 2.7b
Onset of breeding season (ovulation and oestrous)	23 August ± 3.1A	12 August ± 2.3B
End of the breeding season as determined by ovarian activity	24 Feb ± 6.8A	24 March ± 6.4B
End of the breeding season as determined by oestrous and ovulation	28 Jan ± 7.3A	1 March ± 8.3B
Duration of the breeding season as determined by the presence of progesterone (days)	183.0 ± 8.8A	218.2 ± 7.6B
Duration of the breeding season as determined by the presence of oestrous (days)	157.2 ± 9.2A	200.5 ± 8.9B
Ovulation rate at first oestrous	1.33 ± 0.07A	1.79 ± 0.13B
Ovulation rate at last oestrous	1.26 ± 0.07A	1.58 ± 0.08B
Mean nº females showing ovulatory activity (%)	52%A	61%B
Mean nº females showing oestrous and ovulatory activity (%)	42%A	51%B

Different letters in the same row are significantly different (a,b: $P<0.05$; A,B: at least $P<0.01$).