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Influence of pre and postpartum maternal body condition score on the growth of Neuquén Criollo kids

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ABSTRACT

In Neuquén Criollo goat production systems, the sale of goat kids for slaughter is the main source of income. Marketing kids weighing at least 14 kg live weight before 90 days of age improves economic returns due to better meat quality, while also reducing doe lactation requirements and subsequent pressure on grazing land. The present study aimed to evaluate the effect of body condition score (BCS) in does from the Neuquén Criollo breed during the last third of gestation and lactation, on subsequent kid survival, birth weight and growth rate. Thus, two groups of does were penned and fed at two distinct nutritional levels during the last third of gestation and lactation period: High Condition Score (BCS3) and Medium Condition Score (BCS2), to maintain a BCS of 3 and 2, respectively. Kids remained with their dams without nutritional supplementation from birth to weaning. The results indicated that BCS of the dam contributed substantially in the kids' live weight (LW) in different stages: at birth (BW), at slaughter (50 days of age = 50D) and at weaning, (90 days of age = 90D) and these differences were maintained during rearing (220 days of age = 220D). The single and twin male goat kids of the BCS3 group reached slaughter weight (15.16 ± 0.08 and 14.15 ± 0.51 kg, respectively) at 50 days of age (50D), whereas male kids from the BCS2 group did not reach slaughter weight in an equivalent timeframe. Furthermore, the single and twin female goat kids born from BCS3 group between 50 and 90 days of age doubled in weight compared to those born from the BCS2 group. Consequently, single and twin female kids born from BCS3 group only reached 17.52 ± 0.12 kg and 15.52 ± 0.43 L W, respectively, in the first breeding season (220D). Results highlight the need for supplementation management strategies to increase does' BCS during gestation and lactation; in order to improve kids' BW, reduce kid mortality and to ensure target slaughter weights are achieved before 2 months of age. Developing early supplementation strategies in the last stage of lactation before weaning and in the rearing period post-weaning may increase survival and anticipate the reproductive age of female kids.

1. Introduction

The *Capra hircus* species of Neuquén Criollo breed is distributed in the north Patagonian region of Argentina (71° to 69° Long. W – 36° to 38° Lat. S). This specific breed was established due to the introductions made in the 17th century from the Pacific Ocean and has received subsequent inputs from Toggenburg, Saanen, Anglo Nubian and Angora breeds (Lanari et al., 2008) thereby making up its contemporary breed status. The breeding of this species has subsisted under extensive conditions on marginal grazing lands with variable forage production highly dependent on fluctuating precipitation. Additionally this breed is part of the diversified production systems comprised of rural families

that produce meat for self-consumption and for the traditional “chivito criollo” (Criollo kid) market which generally targets Christmas holidays or at the beginning of autumn yet is the main income stream goat producers in this region (Lanari et al., 2005; Zimmerman et al., 2008; Villagra et al., 2015). Zimmerman et al. (2008) found that there are two categories of kids which are commercially marketed in the region with Protected Designation of Origin (PDO): one category up to 3 months of age and other between 5 and 7 months of age. The characteristics of carcass between these categories differ in their size, conformation and composition which need to be accurately and reliably designated to a specific PDO for consumer purchasing decisions. Despite the fact that animals up to 3 months of age are more appreciated for having a lower fat content

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(Zimerman et al., 2008), it is possible that they may not be sold at this age due to an insufficient LW or BCS for the market, as a result of maternal nutrition restrictions during gestation (Villagra et al., 2012).

The growth of tissues related to fetal growth and subsequent lactation may vary as the pregnancy evolves. Placental growth is completed in 100 days (Redmer et al., 2004): the fetus increases 85 % of its final weight (Shelton and Groff, 1974; Redmer et al., 2004) in the last 8 weeks of pregnancy, whereas the development of the mammary gland occurs in the last month of gestation (Rattray et al., 1974). This is the reason why nutrition in the last third of gestation is crucial for the survival of the kids and lactational performance of the dam. Furthermore, it has been found that for other similar goat breeds nutritional management pre- and post-partum influence birth weight, the subsequent growth of kids, and even perinatal mortality (Bajhau and Kennedy, 1990; McGregor, 2016; Luo et al., 2020).

The importance of maternal BCS on BW and kids' growth until weaning (Giraudó et al., 2006) has been established for Angora does in the study region. Yet even with adequate information about average growth rate, BW and LW during the breeding period for Criollo goats (Lanari et al., 2012) in the management region, no information exists about the effect of maternal BCS on these parameters. Still, reports of low BCS prior to kidding and low survival rates are commonly reported from the field (Villagra et al., 2012). Therefore, the aim of this study was to conduct a controlled experiment to investigate the effects of BCS in does during late pregnancy on Criollo kidding losses, kid birth weight and LW at 50, 90 and 220 days of age.

2. Materials and methods

All animal procedures were performed in accordance with the "Guide for the Care and Use of Laboratory Animals" – 8th Edition. National Research Council (2011), the National Academies Press (NAP) Washington, DC. and the "Program of Care and Use for Experimental Animals" by the Virology Institute CICVyA-INTA Castelar (2015).

This study was conducted in the INTA's (National Institute for Agricultural Technology) Agricultural Experiment Station (AES) in Bariloche, Argentina, and its annex farm at Pilcaniyeu, located in the province of Rio Negro at -41.1227848 Lat. S, -71.2502553 Long. W and -41.0317507 Lat. S and -70.5894974 Long. W, respectively, between July 21, 2015 and July 1, 2016.

2.1. Animals and management

2.1.1. Does selection and mating

For this study, 37 multiparous adult does of the Neuquén Criollo breed were provided by the INTA's herd at the Pilcaniyeu Farm. Does were pen mated from May 18 to June 25, 2015. Previously, they were exposed to the close presence of males to generate the effect of buck exposure. Natural controlled mating was conducted using two adult bucks of the same breed. Subsequently, does were kept in grazing paddocks until July 20, when they were relocated to the INTA's AES.

2.1.2. Pre-study and doe treatments

Does were received in the pens' section of INTA's AES on July 21, 2015. For two days they were fed with pelleted lucerne hay and were vaccinated against gas gangrene and clostridial infections. At the same time, samples of faecal matter were taken from 15 does randomly chosen to conduct a stool ova and parasite test in order to detect coccidian and nematodes. The results were negative in all cases, so no treatment was applied. Each animal was identified with an ear tag and their initial LW and BCS were registered.

Twenty eight days after mating was finished, a transrectal ultrasound scanning was conducted for detection of single and twin pregnancies, using a linear transducer with a frequency of 5 MHz (Aloka SSD-500, Tokyo, Japan). After scanning, one non-pregnant doe was removed from the study, leaving 36 pregnant does available for the study. It was

found that 50 % of the does (n = 18) were single-bearing and 50 % (n = 18) were twin-bearing does. Does were separated in two groups, each group consisting of 9 single-bearing does and 9 twin-bearing does (n = 18), and were randomly allocated to BCS2 or BCS3 nutritional treatment, resulting in two homogeneous groups; LW was 39.2 ± 1.65 and 37.26 ± 1.19 for BCS3 and BCS2 respectively. BCS was 2.32 ± 0.06 and 2.26 ± 0.07 for BCS3 and BCS2 respectively.

2.2. Feed intake

During mating and the first seven weeks of gestation, does grazed on natural neneo (*Mulinum spinosum*) and coirones (*Poa ligularis* and *Festuca pallescens*) grasslands at the INTA's farm. Once they entered the INTA's AES, both groups were housed daily in separate pens and were fed pelleted lucerne hay in a proportion of 0.845 Kg. DM/animal/day for 2 days. From the third day on, does from the BCS2 group were given a restrictive feeding with pelleted lucerne hay (16 % CP and 2.3 MCal ME/kg.DM), 10 % less than the energy requirements of maintenance, considering a weight loss of 50 g/day (1.3 MCal/ME/day) until reaching an average BCS of 2 (Table 1). Feeding assignments varied between 0.420 and 0.680 Kg.DM/animal/day. The BCS3 group had an ad libitum feeding consisting of a mixture (16 % of CP and 2.8 MCal. ME/kg.DM) of pelleted lucerne hay (56 %), maize grain (29 %) and soybean expeller (15 %) until reaching an average BCS of 3 (Table 1). In this case, assignment of the mixture was of 1.8 kg. DM/animal/day, observing a rejection between 5% and 10 % for covering a daily requirement per doe of 4.2 MCal.ME/kg/DM. Both groups were fed in the morning between 8 and 9 a.m. and were given ad libitum access to water in the indoor shelter. Two does, one belonging to the BCS3 group and the other to the BCS2 group, pregnant of twins and single respectively, were discarded at this time due to lack of adaptation to the enclosure and feeding conditions. Therefore, each group continued the experiment with 17 goats. Targeted BCS were obtained at 64 days prior to the average parturition date. From then on, feeding was adjusted weekly after weighing the animals so as to fulfill maintenance and gestation requirements and to control that there were no variations in the BCS. During the last third of gestation, food rations for the BCS2 treatment ranged from 0.760 to 1.100 Kg. DM/animal/day and from 1.560 to 1.730 Kg. DM/animal/day for BCS3, whereas during lactation food rations reached 1.200 Kg. DM/animal/day and 1.800 Kg. DM/animal/day respectively.

In every stage, food rations per animal were recalculated weekly as proposed by Freer et al. (2007) taking into consideration the weekly registry of LW, BCS, physiological stage, litter size and day of gestation in pregnant does, while kids' ADG, litter size and lactation day were assessed for lactating does. This methodology allows using the individual registry of LW and the BCS in the prediction of animal performance at the level of group or herd (Freer et al., 2007). Does from both groups had unrestricted access to water and to a mineral supplement in block form with 6.42 % of phosphorus, 12.84 % of calcium, 0.03 % of copper,

Table 1

Ingredients and chemical composition of diets provided to two groups of does fed differentially during the last third of gestation and lactation period: High Body Weight (BCS3) and Medium Body Weight (BCS2).

	BCS3	BCS2
Percent as-fed basis		
Alfalfa pellets	55	100
Corn grain	29	–
Soybean expeller	15	–
Nutrient composition *		
DM%	86.7	84.5
ME, Mcal/kg	2.8	2.3
CP%	16.0	16.0
Ca%	0.85	1
P%	0.24	0.35

* Based on analyzed chemical composition of individual ingredients.

0.2 % of iron, 0.045 % of sulphur, 0.01 % of iodine, 0.005 % of cobalt, 0.025 % of zinc, 0.02 % of magnesium and 0.01 % of tannin.

2.3. LW and BCS measurement

Does were weighed weekly using an electronic scale (Balcopan S.A) with a sensitivity of 100 g in a weighing cage, always in the morning before feeding. BCS, as well as LW, were measured with the same frequency, assigning a grade from 1 to 5 as proposed by Jefferies' (1961) for sheep. The method of condition scoring, was adapted from the system described by Jefferies (1961), consisting of evaluating by palpation of the prominence of the spinous processes of the anterior lumbar vertebrae. The sharpness and degree of cover of the ends of the transverse processes and the extent of the muscular and the adipose tissues beneath them, evaluated by spanning the lumbar vertebrae with the fingers and the thumb. The evaluation of the depth of the longissimus dorsi muscle and the degree of subcutaneous fat coverage was conducted by palpating the region between the spinous and transverse processes. The condition scores range on a 5-point scale from Grade 1: extremely emaciated and at the point of death, to Grade 5: over fat. This scale was modified adding intermediate grades of half point (Russel et al., 1969) and its use has been extended for does (Hervieu et al., 1989; Delfa et al., 1995; Domingo et al., 2009). BCS determined at the loin region in non-dairy goats has been studied by McGregor (1992 and 2011), who found a correlation with total body fat content. Similar results have been found for Criollo goat (Domingo et al., 2009). There is evidence of the use of BCS, for referring to the nutritional state of does, gestating or lactating, and its relation with parameters of kids' growth (Giraud et al., 2006; McGregor, 1992; McGregor, 2010, 2011).

2.4. Kidding management

Four days before the parturition, both groups were allocated in two different, bigger pens according to their treatment. These pens were prepared for kidding, with free access to a shed. Kidding started 86 days after the beginning of the study, but the bulk occurred between day 100 and 110. After kidding, kids and their dams were moved to a small indoor shelter until 9 a.m. of the following day. After that, goat kids were separated from the does, which were moved to the original pen. From birth, kid and doe were observed the first 24 h to verify colostrum intake. When better environment conditions and feeding assistance were needed, they were penned together. Each kid was weighed and identified with an ear tag within eight hours after birth. Each morning kids were separated from does and were moved to a recreational pen without access to food or water. They were kept there for seven hours and then returned to each doe until the next day. This management simulated the breeding conditions in the Criollo doe production system, which allows extensive grazing for the does and the safeguard of the kids in pens (Lanari et al., 2005). This procedure was repeated daily throughout the entire lactation period. Fecal samples of 15 kids randomly chosen and 27 ± 2 days old, were taken and oocysts per gram (OPG) were quantified to evaluate the internal parasite burden, which were minimal throughout the course of the study. Food rations reached 1.95 kg DM/animal/day for BCS2, and 2.42 kg DM/animal/day for BCS3 between the third and fifth week of lactation.

Birth weight, sex, litter size and date of birth were recorded at kidding. Additional record keeping of degree of assistance at birth or if any other post-partum interventions of the doe or kid were recorded. Male kids were slaughtered when they exceeded 14 kg of target LW (slaughter weight) between 50 and 90 days of age. Although weaning on ranches in the region normally occurs at 90 days after birth, in our study, because births were not synchronized and to ensure that all kids were at least 90 days old at weaning, female kids were weaned at 121 days from kidding beginning.

2.5. Statistical analysis

A completely randomized experimental design was used, with two treatments. Three factors with two levels each were considered; maternal nutritional level (BCS3/BCS2), litter size (Single/Twin) and sex (Male/Female). A descriptive analysis of the mortality results was made, as well as requirements of assistance to the parturition according to nutritional treatment. A database of weights corrected by linear interpolation was elaborated with the information about weights and ages of each kid for 50, 90 and 220 days of age, as well as birth weight. This information was used to analyze the effects of maternal nutritional level, litter size, and sex (as main effects) and their interactions using an analysis of variance. When interactions were significant or marginally significant mean squares for the separated analysis of variance was calculated to compare within each factor the nutritional level in order to follow the main aim of this study. Each date is important in management terms (birth, 50, 90 and 220 days of age), and they represent approximately a moment of the calendar of management of the real production system; weight at 50 days (50D) is associated with slaughter weight, weight at 90 days (90D) is associated to weaning and weight at 220 days (220D) is associated to the first breeding season in the life of the animal and its likely commencement of puberty.

Variables BW, 50D, 90D and 220 W were analyzed in a separate way for males and females. The effect of the does' nutritional level was analyzed in every case. For the males whose destiny was normally slaughtering, the effects for BW and 50D were analyzed. As regards the females whose main destiny was to become a replacement category, BW, 50D, 90D and 220D were analyzed. The effect of litter size was considered, for BW, 50D, 90D and 220D.

The following model was used for analyzing LWs concerning specific moments: birth (BW), 50 days of age (50D), 90 days of age (90D) and 220 days of age (220D).

$$Y = \mu + a + b + c + e$$

Where:

- Y is the kids' LW
- μ is the population mean
- a is the effect of the maternal nutritional level
- b is the effect of the litter size
- c is the effect of sex
- e is the error

Heterogeneity of the variance was considered in the ANOVA analysis of 50D for males and 90D and 220D for females. On the other hand, homogeneity of the variance was considered in the model used for females, in the analysis of BW and 50D. For all cases a level of significance of 5% was used. LWs 50D, 90D and 220D were correlated with birth weight (BW) for the kids of both sexes.

Gompertz and Logistic models were adjusted for kid data to obtain growth curves.

For all the analysis mentioned, the statistical software InfoStat was used (Di Rienzo et al., 2012)

3. Results

3.1. LW and BCS of does

In the initial phase of the study changes in BCS were achieved due to differential nutritional composition. There was a BCS increase of 0.75 for the BCS3 group and a decrease of 0.25 for the BCS2 group during the first six weeks of the test. The changes in doe' BCS and LW from the beginning of the last third of gestation to weaning are shown in Fig. 1 and Fig. 2, respectively. Across all the periods and in the same dates, BCS and LW of the BCS3 group were higher than the BCS2 group. On the other hand, both groups maintained BCS until parturition, with a minor decrease in the first phase of lactation followed by a recovery. At the

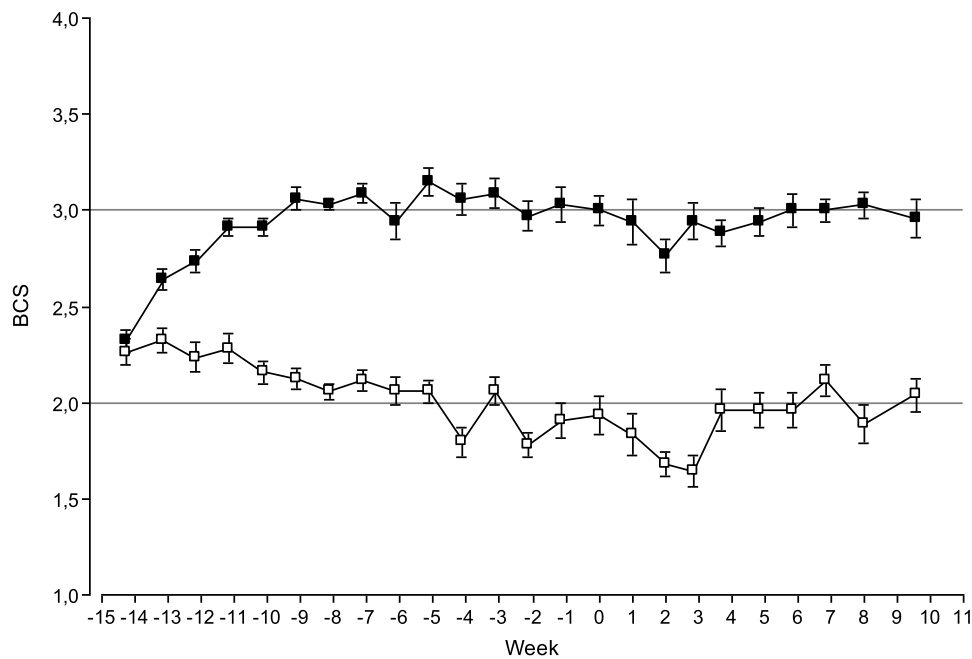


Fig. 1. Body condition score (BCS) of Neuquén Criollo does during pregnancy (week -15 to 0), and lactation (week 0 to 11) which s.e. bars plotted for all data points (n = 17 for each treatment). Symbols: ■, BCS3 treatment; □, BCS2 treatment.

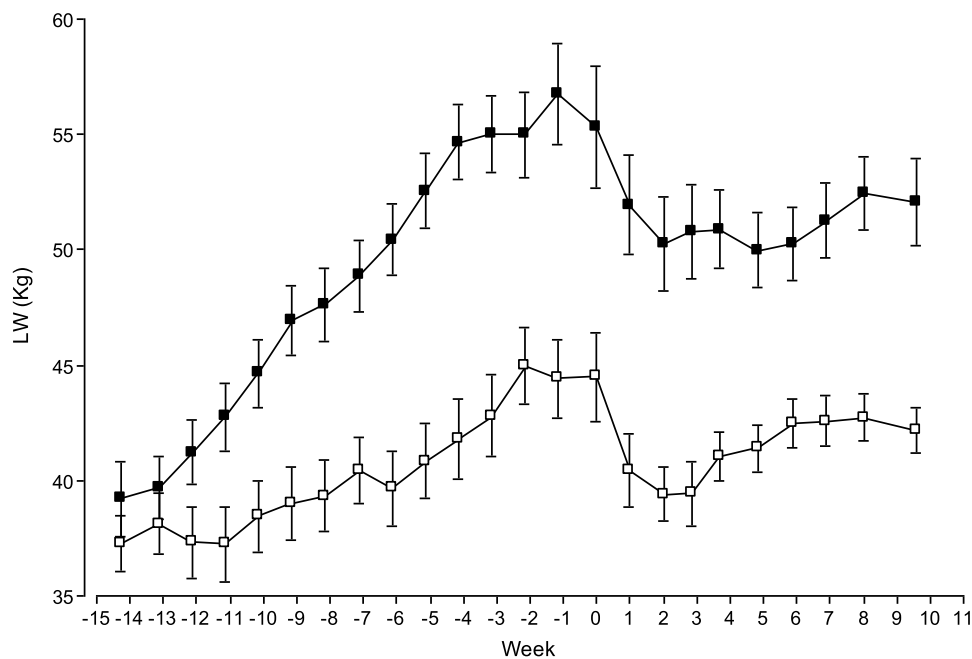


Fig. 2. Live weight (LW) curve of Neuquén Criollo does during pregnancy (week -15 to 0), and lactation (week 0 to 11) which s.e. bars plotted for all data points (n = 17 for each treatment). Symbols: ■, BCS3 treatment; □, BCS2 treatment.

beginning of the study, there was an increase in LW associated with an advancement of gestation, which decreases strongly in the week with greater concentration of parturitions and has a minor increase in late lactation.

3.2. Mortality, LW and kids' growth

As regards mortality, one case (3.8 %) of abortion was observed 10 days before the first parturition and 15.4 % of perinatal deaths in BCS2. There was a 100 % survival of kids and no abortions in BCS3. Forty eight

hours after kidding and until weaning there was no mortality in any of the groups. However, 19.3 % of the single and twin BCS2 kids required assistance at birth. There was only once case of mortality in twins', with almost the totality of the kids that were bred as twins were later raised in this same condition (94.1 %).

From the BCS3 nutritional level, 8 kids were born by single birth (5 females and 3 males) and 18 kids were born as twins (12 females and 10 males). From the BCS2 nutrition level, 8 kids were born by single birth (5 females and 3 males) and 17 kids were born as twins (7 females and 10 males) (Table 2).

Table 2

Live weight (LW, Kg) of Neuquén Criollo female and male kids, and differences at birth (BW), at 50 (50D), 90 (90D) and 220 (220D) days of age, according to Nutritional level (BCS3 or BCS2) and type of parturition or breeding (Single or Twins). (Mean \pm standard error). Values with * indicate p-value <0.05, ** p-value <0.01 and *** p-value <0.001. Values in brackets show amount of kids (n).

	Sex	Litter size	Nutritional level			Interactions (p-value)		
			BCS3	BCS2	Difference (kg)	Nutritional level x Sex x Type of parturition	Nutritional level x Type of breeding	
BW	Male	Single	3.79 \pm 0.09 (3)	3.11 \pm 0.26 (3)	0.68*	0.0487		
		Twin	3.79 \pm 0.17 (6)	2.38 \pm 0.12 (10)	1.41**			
	Female	Single	3.49 \pm 0.12 (5)	2.81 \pm 0.25 (5)	0.68**			
		Twin	3.00 \pm 0.10 (12)	2.57 \pm 0.16 (7)	0.43*			
50D	Male	Single	15.16 \pm 0.08(3)	14.15 \pm 0.51 (6)	4.29**	0.0264		
		Twin	10.87 \pm 1.07 (4)	6.71 \pm 0.49 (7)	7.44**			
	Female	Single	13.52 \pm 0.65 (5)	6.66 \pm 0.42 (3)	6.86**			0.0659
		Twin	11.08 \pm 0.45 (12)	6.61 \pm 0.49 (7)	4.47**			
90D	Female	Single	17.91 \pm 0.75 (5)	8.65 \pm 0.18 (3)	9.26**	0.0053		
		Twin	14.15 \pm 0.78 (10)	8.7 \pm 0.53 (7)	5.45**			
220D	Female	Single	17.52 \pm 0.12 (5)	10.29 \pm 0.19 (3)	7.23***		0.0749	
		Twin	15.52 \pm 0.43 (9)	10.74 \pm 0.46 (5)	4.78***			

The results of BW are shown in Table 2, registering greater BW from BCS3 kids. There were significant interactions ($p = 0.0487$) in nutritional level x litter size x sex and nutritional level x sex ($p = 0.05$). Single males and females born from BCS3 does are respectively 24 % and 21 % heavier than those born from BCS2 does, whereas male and female twins born from BCS3 does are respectively 17 % and 59 % heavier than those born from BCS2 does.

For the males, a significant interaction between the nutritional level and litter size was found at 50 days of age (50D) ($p = 0.0264$). Single BCS3 males were 40 % heavier than BCS2 males, while this difference increased to 110.88 % for twins.

Table 2 shows female kids' LW at 50(50D), 90 (90D) 220 (220D) days of ages. At 50 days of age there was a marginally significant interaction between the nutritional level and the litter size ($p = 0.0659$), where single BCS3 female kids exceeded the average weight of the BCS2 ones in 103 %. This difference was 68 % for the case of female twins. Moreover, there was a significant interaction between the nutritional level and the litter size ($p = 0.0053$) when analyzing weights at 90 days of age. In this case, single BCS3 females were 107 % heavier than BCS2 females, but this difference was reduced to 63 % for twin females. These significant differences ($p < 0.0001$) between nutritional levels were reduced to 70 % and 45 % for 220D for single kids and twins, respectively. There was a marginally significant interaction between the effects: nutritional level x litter size ($p = 0.0749$). Minor compensatory growth was observed in BCS2 for the twin females that exceeded LW of single born kid goats. LW differences were calculated for each of the ages, as well as nutritional levels and litter size, making hypothetical testing for contrasting the nutritional level (Table 2). The correlation coefficient among 50D, 90D and 220D with the BW of the female kids is 0.83, 0.82 and 0.75, respectively; whereas 50D with the BW of the males is 0.91.

4. Discussion

Changes in LW resulting from the different nutritional treatments achieved the targeted experimental objectives of growth trajectories that were significantly divergent from the beginning of the study. The BCS3 does showed an increase in LW of 17.54 kg during the 15 weeks of gestation until parturition, whereas BCS2 does maintained LW from weeks 15 to 11, then it increased 7.7 kg until parturition. These changes in LW reveal directly the changes in the intake of metabolizable energy (ME) during gestation and lactation (Fig. 2). Prepartum and lactation growth curves showing LW and BCS are similar to those described in a work with Criollo breed does in Mexico (Isidro-Requejo et al., 2017). However, these results differ slightly from those obtained by McGregor (2016), who provided a different nutritional treatment for Angora does in the second third of gestation and kept similar levels of energy until

parturition.

Metabolized Energy intake was significantly different between treatments since the first week of the experiment. In order to maintain the weight between week 15 and 11 of pregnancy in the BCS2 treatment, ME intake had to be reduced by 15 % (Fig. 2). These findings show that, in field situations, dams that lose weight during the half of gestation undergo significant reductions in their ME intake in relation to maintenance requirements.

Starting from the 9th week of pregnancy, ME restrictions on BCS2 treatment were removed. From the 5th week before delivery, both BCS2 and BCS3 treatments showed a similar pattern of weight gain until parturition and a subsequent decrease until reaching a balance during lactation. This information shows that for this particular breed, the difference of 1 point in BCS is equal to around 8 or 10 kg of LW (Fig. 2), similar to 9.4 kg per unit of BCS reported for Angora goats (Mc Gregor 2009). The association between BCS, determined at de loin region, and LW can be quite high with regression coefficients as high as 0.93 (Mc Gregor 2011).

Total body fat is highly correlated with LW in non-dairy goats (Mc Gregor 1992). In this case both doe groups exhibited similar LW and BCS at week 14 until parturition, therefore, we attribute the difference in kids growth to the difference in BCS of the goats

4.1. Effect of the nutritional level on birth weight

Does' BCS exerts marked effects on reproductive performance in terms of abortions and perinatal mortality (Mellado Bosque et al., 2001; Bajhau and Kennedy, 1990; Lanari et al., 2005) No abortions or perinatal mortality were registered when does had a BCS = 3 in late gestation, compared with 3.8 % of abortions and 15.4 % of perinatal deaths in does with a BCS = 2. These results indirectly suggest an increase in perinatal losses and abortions due to the association with low prepartum BCS (Villagra et al., 2012).

This study also shows that the effect of the does' BCS on kids' BW was significant in every case, by comparing animals of the same sex and that have shared the same litter size (Table 2). In the current study a BCS (3 and 2) generated differences of 680 grs in BW for single males and females; and 430 and 1400 grs, respectively, for twin males and females. These values are higher than the 10.3 % reported in similar studies with Criollo does on extensive conditions (BCS 2.5) supplemented with 0.6 kg of corn/day during 20 days before parturition, gave birth to kids 400 grs heavier than does which were not supplemented. Interestingly, both groups lowered their BCS to values close to 2 at kidding, which suggests that the increase in fetus' LW is not only influenced by BCS, but also by supplementation.

Birth weight of single and twin kids of the BCS3 and BCS2 groups

were in general higher than the 2.5 kg reported by Lanari et al., 2005 in the study region; except for the twin males of BCS2 (BW = 2.38 kg). Birth weight of single males and females, and twin males corresponding to BCS3 were higher than the 3.2 kg reported by Bajhau and Kennedy (1990) for Criollo kids that were bred in a grazing environment of high nutritional value. As has been mentioned before, BW is one of the main survival factors (Shelton and Groff, 1974; Assan, 2013; Oldham et al., 2011; Terrazas et al., 2012) and this is even more important in real systems where this breed is raised, since climate conditions during parturition tend to be more unfavorable than in this study. This would indicate that in our study the conditions of BCS3 were better than in extensive systems and that conversely, in the region, Criollo goats may have BCS lower than 2 at kidding, which translates into lower BW for kids.

The BCS2 treatment had 18 % mortality and 20 % assisted births, whereas the BCS3 group had 0% of mortality and there was no assistance required at parturition. This is likely attributable to kids' higher BW in BCS3 compared to BCS2. These results are in agreement with several previous studies (Hodge, 1966; Van Der Westhuizen, 1971; Shelton and Groff, 1974; Hobson et al., 1986; Holst et al., 1986; Oldham et al., 2011; Terrazas et al., 2012; Assan, 2013; McGregor, 2016) and suggest that Neuquén Criollo does having BCS = 2 during late gestation may experience decreased survival and performance, whereas reaching BCS = 3 during late gestation, they gave birth to heavily enough kids to ensure 100 % of survival, without need of birth assistance.

Differences in does' LW and BCS achieved between treatments in late pregnancy suggest that a high energy supplementation would increase kid BW and, consequently, kid survival. McGregor (2016) found that nutritional manipulation in the second third of gestation did not affect the BW of the Angora kids when the does were allowed libitum feeding during the last third of gestation. Nevertheless, the same study found that LW before kidding was positively correlated with the BW of the kid, since an increase of 10 kg in the LW of the doe in day 137 of pregnancy increased kid BW in 0.3 kg. Hobson et al. (1986) reported that kids' BW increased 500 g when the doe was fed 530 g/ day of cereal grains. In the

same study, supplemented does gained 15 kg of LW in a linear way during all the pregnancy, whereas does that were supplemented 200 or 400 g/d had an increase of LW of 9–11 kg, but without effects or minor effects upon BW. These results confirm does' capacity to compensate increasing their LW upon any nutritional restriction experimented at the beginning of gestation, provided that almost libitum feeding is provided during the last third of gestation. Thus, an under nutrition at the beginning compensated with high doses of energy in the last third of gestation, annuls or decreases significantly any negative effect in the BW of the kids.

The results on survival in this study have a direct implication on the production systems. We found reproductive losses in BCS2 treatment, which imitated local conditions of LW loss during pregnancy. Since producers do not perform prepartum ultrasounds, these losses are invisible and, thus, they may attribute them to other factors. Based on these results, an energetic supplementation (mixture of 80 % maize and 20 % soybean expeller or commercial concentrate, containing at least 2.9 MCal. ME/kg.DM and 16 % CP) of more than 500 g / day to pregnant does with BCS 2 or less would increase kid survival.

4.2. Effects on male growth

Significant differences between BCS3 and BCS2 in single and twin male kids at 50D were found (Table 2). Within the BCS3 group both singletons and twins reached the slaughter weight of 14 kg LW, before reaching 60 days of age (Fig. 3), and twins duplicated the 50D weight of BCS2 twins. Moreover, the 50D of singletons and twins of BCS3 were almost 50 % heavier than the LW of 10.5 kg corrected at 60 days, informed for this local breed in extensive conditions (Lanari et al., 2005) and very close to the 16.3 kg reported for kids of the same breed at 3 months of age, also raised in extensive conditions (Zimmerman et al., 2008). This may be explained by the fact that higher BW provides a higher suckling capacity for kids, which influences the capacity of milk production of does (Assan, 2013), and thus, generating a kind of virtuous cycle. These results suggest that adequate doe nutrition during

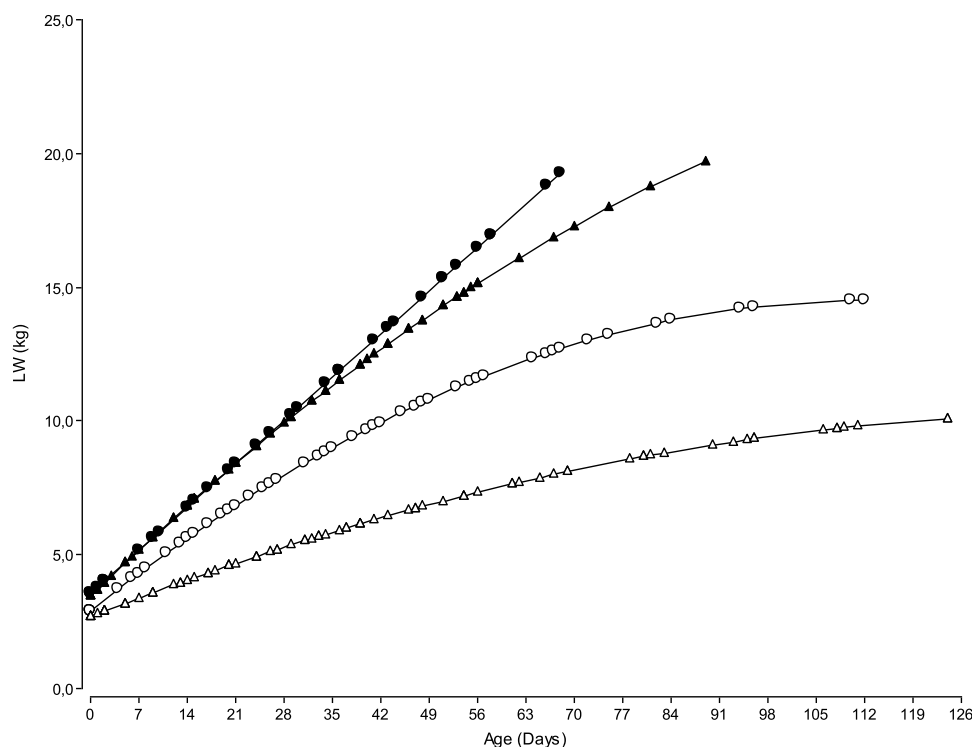


Fig. 3. Live weight (LW) curve of Neuquén Criollo male kids from birth to slaughter. Single BCS3 treatment (●); Twin BCS3 treatment (▲); Single BCS2 treatment (○); Twin BCS2 treatment (△).

late gestation and early lactation would allow for single and twin kids to be sold before 3 months of age, with its consequent improvement in the quality of meat (Zimmerman et al., 2008), reaching higher prices, reducing the lactation period and, consequently, doe requirements. This may bring important production benefits since it improves does' possibilities of getting pregnant in the next mating and also, reduces significantly the DM intake in grazing lands. On the contrary, singletons born from does with a BCS 2 or less may only be sold after 120 days (Fig. 3), while twins will never reach the slaughter weight remaining with their does. This increases the possibility of losses due to predation, and raises the lactation requirements of the does. Male kids not sold during the summer due to underweight would have a higher risk of death from undernourishment in the following winter (Villagra et al., 2012).

In a study on extensive conditions of Saanen kids in Turkey, Dınçel et al. (2019) found that average LWs at birth, at weaning, at 60, 90, 120 and 180 days of age were 3.05 kg, 11.80 kg, 12.26 kg, 14.20 kg, 17.41 kg and 25.01 kg, respectively. Din et al. (2019) studied the growth of the Damani local breed in the mountains of Pakistan and found a BW of 2.71 kg, 6.50 kg at weaning, and for 4, 5, 6, 7, 8 and 9 months of age LW were 9.16 kg, 12.01 kg, 14.14 kg, 16.30 kg, 18.16 kg and 23.56 kg, respectively. Even though the weights found at birth were similar in all the cases, weights at 90 days in Criollo does were superior in the two treatments reported herein.

4.3. Effect on females' growth

There were significant LW differences at 50, 90 and 220 days of age in single and twin female kids between treatments. BCS3 female kids double the LW of BCS2 during lactation (Table 2; Fig. 4). At the end of lactation and during the grazing phase as of 90–100 days, these differences were reduced although they remained significant. There was minor compensatory growth for the BCS2 kids, which can be attributed to higher maintenance requirements for heavier kids. Freer et al. (2007) reported a reduction of growth rates for young categories of small ruminants due to lack of protein content in winter in mild pastures. Due to

the weaning effect and its consequent change in nutrition, single females of the BCS3 group barely reached an average weight of 17.5 kg at 220 days; that is, a 46 % of adult weight and 15.5 kg for the twin ones. This indicates that the energy content of the grassland does not satisfactorily cover female kids' nutritional requirements. Future studies should evaluate the effects of energy supplementation on the LW of the female kids after weaning.

5. Conclusions

The results of this study showed that BCS = 3 during late gestation and lactation of the Neuquén Criollo does, improve birth weight. Moreover slaughter weights of 14 kg can be reached for both single and twin males before 60 days of age. On the other hand, does having BCS = 2 during late gestation and lactation deliver light kids, reducing kid survival, and kid slaughter weights are reached only for single male kids after 90 days of age. These results are of major importance for Criollo goats' production systems since the sale of kids for slaughtering constitutes the main source of farmers' income. Hence obtaining kids with slaughter weight before 90 days of age improves the quality of meat, reduces gestation requirements and the time of exposure to predators and decreases pressure on natural grazing lands. However, even for single kid females born of does with BCS = 3, weaning reduces dramatically the daily weight gain reaching less than 50 % of adult weight at 220 days of age.

These results highlight the need of studying supplementation strategies to increase does' BCS during gestation and lactation; in order to improve kids' BW, and to ensure slaughter weights before 2 months of age.

CRediT authorship contribution statement

Esteban Ricardo Jockers: Conceptualization, Investigation, Data curation, Formal analysis, Writing - review & editing. **Victor Hugo Medina:** Conceptualization, Methodology, Supervision, Writing -

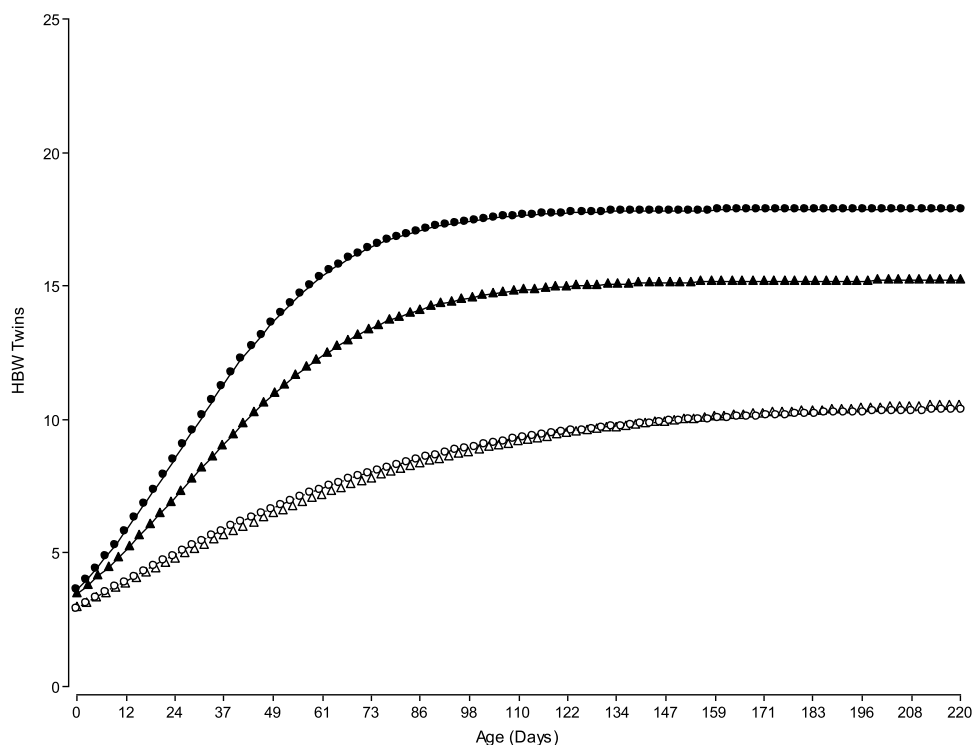


Fig. 4. Live weight (LW) curve of Neuquén Criollo female kids from birth to day 220. Single BCS3 treatment (●); Twin BCS3 treatment (▲); Single BCS2 treatment (○); Twin BCS2 treatment (Δ).

review & editing. **Edgar Sebastian Villagra:** Methodology, Supervision, Project administration, Funding acquisition, Investigation, Writing - review & editing.

Declaration of Competing Interest

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We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

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