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Effects of nutrition level during lactation and rearing periods on growth patterns, puberty onset and fertility rate in beef heifers

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ABSTRACT: This study analysed the effects of different nutrition levels from heifer birth to first Timed Artificial Insemination (TAI) at 15 months, on their growth patterns, puberty onset and fertility rate. Twenty-nine Parda de Montaña heifers, born in autumn, were assigned to two growth rates in the lactation period (0-6 months: 700 *vs.* 1000 g/d, to Low (L) and High (H), respectively) and in the rearing period (6-15 months: 700 *vs.* 1000 g/d, to Low (L) and High (H), respectively), resulting in 4 treatments: LL, LH, HL, HH. At 15 months of age an Ovsynch protocol with an intravaginal progesterone device was used to synchronize and breed the heifers. Weight was taken weekly from birth until breeding season was finished to study the evolution of weight and average daily gain (ADG) along the experiment. Heifers were bled weekly throughout the rearing period to determinate the onset at puberty through plasma progesterone concentration. Heifers' average daily gains were influenced by the lactation and the rearing nutrition levels, animals compensating the growth rates in the different phases. The age at onset of puberty was higher in the animals receiving the Lactation low nutrition level ($P<0.01$) and the Rearing low nutrition level ($P<0.001$). Heifers of all lots showed similar weights at onset of puberty (55% adult weight), conception age (16.4 months) and fertility rate (89%). It can be concluded that the advance of the first service from 21 to 15 months of age is possible in extensive systems of beef cattle, if growth rates of 1 kg/d during lactation or/and rearing are guaranteed. Additional research is needed to determinate the impacts on adult size and frequency of dystocia at first and subsequent calvings of early-bred heifers.

Key words: efficiency, management, performance, replacement, reproduction

INTRODUCTION

Development of heifers is a critical component of beef production enterprise (Grings *et al.*, 2007) because they are the future dams and the efficiency in beef production is based on dams' productivity. This productivity could be defined by reproductive performance, capacity to wean calves at relatively heavy weight and lifespan. Those aspects could be influenced by heifers' management from birth to first breeding. Therefore, heifers must be keep a specific replacement program to reach first calving at early age with sufficient development to avoid dystocia at first and subsequent calvings, and to ensure a long and efficient lifespan (Patterson *et al.*, 1992). However, in Spain sometimes due to extensification of beef cattle production (García-Martínez *et al.*, 2009) and other ones due to reduced size of farms, heifers do not get this differentiated management.

Growth rate, both before and after weaning, could influence in productive and reproductive performance such as weaning weight, adult body weight (BW), age at onset of puberty, fertility at first breeding, etc.

Onset of puberty is the essential first step in replacement heifers' process (Revilla *et al.*, 1992) and there are several major physiological, environmental, and managerial factors that can advance or delay the age at puberty Schillo *et al.* (1992) described that puberty is reached with a critical BW for each breed. The main objective should be that the most heifers reach that critical weight early to reach puberty and cycle regularly before the breeding season to improve conception rate at first artificial insemination (AI). Beef heifers that calve by 2 years of age have a greater lifetime production potential than heifers that calve at older ages (Patterson *et al.*, 1992). In order to achieve this goal, heifers must reach puberty before 12 to 13 months of age, conceive at 14 to 15 months of age, and calve at approximately 2 years of age (Schillo *et al.* 1992).

The objective of this experiment was to evaluate the effect of different feeding level from birth to first breeding (lactation (Lact, 0-6 months) and rearing (Rear, 6-15 months) period) on BW, average daily gain (ADG), onset of puberty and fertility after fixed-time artificial insemination (TAI) at 15 months of age.

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MATERIAL AND METHODS

Management

The study was conducted in La Garcipollera Research Station, in the mountain area of the central Pyrenees (Spain 42°37'_N, 0°30'_W, 945 m a.s.l.). Twenty-nine Parda de Montaña (beef breed derived from Brown Swiss) heifer-calves born in autumn (average birth date 12 October) were used for this study. At calving cow-calf pairs were randomly assigned to one of the four management strategies in a 2 x 2 factorial experiment, combining two heifer growth rates in the lactation period (0-6 months: 700 *vs.* 1000 g/d to Low (L) *vs.* High (H), respectively) and two in the rearing period (6-15 months: 700 *vs.* 1000 g/d to Low (L) *vs.* High (H), respectively)). Treatments were randomly balanced according to dam BW and body condition score (Lowman *et al.*, 1976), calf birth date and birth BW. Treatments: LL, LH, HL, HH.

Cow-calf pairs remained indoors throughout lactation in a loose-housing system with straw-bedded pens (one pen per treatment). Dams were fed in groups a total mixed ration to met maintenance requirements for energy and protein in a 580 kg beef cow producing approximately 9 kg of energy-corrected milk (NRC, 2000). Calves were kept in straw-bedded cubicles adjacent to their dams and allowed to suckle them twice daily for 30 min. In order to achieve the desired growth rates LactH heifers had free access to starter concentrate.

At six months (175 d, mean), calves were weaned and transported to CITA Research Station facilities (41º43'_N, 0º48'_W; 225 m a.s.l.) where the rearing period was carry out. In that period heifers were housed indoors in a loose-housing system with straw-bedded pens. Each group of heifers had a pen with fresh and clean water supplied *ad libitum*.

Throughout this period, to achieve desired rate gain, heifers were group-fed alfalfa hay *ad libitum* and 6g or 12g concentrate/kg BW to low daily gain (RearL) or high daily gain (RearH), respectively.

At 15 months was started 90 days of breeding season. An Ovsynch protocol with TAI was used to synchronized and breed the heifers. After TAI heifers were observed twice daily to detect the heat in the non-pregnant heifers and to proceed to insemination approximately 12 h after the detection of estrus.

First-service conception and overall pregnancy rates were determined by transrectal ultrasonography (Ultrasound: Aloka SSD-500V (Aloka, Japan), equipped with a linear-array, 7.5-MHz transducer) 31 d after TAI and 31 d after the conclusion of the breeding season.

The TAI day was taken to determine the age and body weight at first breeding. The number of AI required to get pregnant was recorded for every pregnant heifer and the last AI day was taken to determine the age and body weight at conception.

BW at first breeding and at conception was calculated as average weights at the TAI or last AI day, respectively, previous and subsequent weight.

First-service conception rate was determined as heifers pregnant at the TAI by total heifers. Conception rate was determined as total heifers pregnant in the breeding season by total heifers.

Feedstuff and intake

During lactation period dams were milked monthly to determine the calves' daily milk intake. In addition, LactH groups had free access to starter concentrate and their intake was group-recorded daily. The feed refusal was removed and weighed weekly.

Throughout rearing period alfalfa hay intake was group-recorded weekly. The concentrate intake along this period was group-recorded daily and it was monthly adjusted by average group-weight.

Body Weight

Heifers were weighed, before morning feeding without prior deprivation of feed and water, once a week throughout the experiment. BW at experiment's key points was calculated as average of three consecutive weights. Heifers' average daily gain for each period was calculated by linear regression of weights against time.

Blood Sampling and Assays

Heifers were bled from coccygeal vein or artery weekly throughout the rearing period to determinate the onset at puberty through plasma progesterone concentration. Samples were taken into 9 ml heparinized tubes (Vacuette, Spain) and were centrifuged at 3500 min^{-1} for 20 min at 4 ºC immediately after collection and the plasma was harvested and frozen at -20ºC until it was analyzed.

Plasma progesterone concentrations were measure using a commercial enzyme immunoassay kit (Ridgeway Science, UK).

Age at puberty was defined as 7 d before the date of collection of the first blood sample that contained >1 ng/ml of plasma progesterone. Puberty ADG was calculated by linear regression of birth-puberty weights against time.

We took the weaning day as date of onset at puberty for pubescent heifers at the beginning of rearing period. In addition, first day of synchronization protocol was taken as date of onset at puberty for prepuberal heifers at that moment.

Statistical Analysis

Data were analyzed as a completely random design using the GLM procedure of SAS (v.9.3; SAS Inst. Inc., Cary, NY), with nutrition levels at lactation and rearing phase and their interaction as fixed effects. Means were separated using LSMEANS procedure of SAS and *P*-values £ 0.05 were considered different. Fertility was analyzed using FREQ procedure of SAS (chi^2 test).

RESULTS AND DISCUSSION

Along lactation phase, with a similar milk intake (7.2 kg/d), provision of concentrate *ad libitum* (mean intake: 1.37 kg/d) allowed to LactH treatments reach greater ADG (1.063 vs. 0.672 kg/d to LactH and LactL, respectively, P<0.001). Both in the first trimester of this phase like, more intensively, in the second one due to the increased intake from 0.2 kg/d in the first month to 3.45 kg/d in the last one (Table 1). Similar quantities to those described by Blanco *et al.* (2008) in feeding calves under the same conditions.

During rearing period, the gains were influenced by feeding level at this period, with greater gain in heifers RearH than RearL (0.668 *vs.* 0.960 kg/d, respectively, P<0.001). This difference maybe was due to a lower concentrate intake (4.2 *vs.* 1.7 kg/d to RearH and RearL, respectively) that RearL treatments partially offset with a greater alfalfa hay intake (5.2 *vs.* 6.8 kg/d to RearH and RearL, respectively). In the same way, gains in this phase were influenced by the performance in the previous phase. LactL treatments had higher growth rate during rearing phase (0.870 vs. 0.759 kg/d to LactL and LactH, respectively, P<0.001) partially offsetting lower gain observed in the previous phase. This compensatory growth was more intensive in the first two trimester of rearing period and in the last one there were no differences between treatments. The concentrate and hay intake was similar for both treatments (2.9 and 6.1 kg/d of concentrate and hay, respectively). In view of these results would think of higher conversion efficiency in animals with compensatory growth (Hoch *et al.*, 2005). Despite this higher growth, compensation was not complete, due to the marked difference weight at weaning (164 *vs*. 228 kg to LactL and LactH, respectively, P<0.001) (Figure 1), and the difference weights persisted between treatments at 15 months (414 *vs.* 455 kg LactL and LactH, respectively, P<0.01).

No differences were found in BW at onset of puberty between treatments (mean BW = 324 kg) (Table 2) confirming that puberty is reached with a critical BW for each breed (Schillo *et al.* 1992), in this case (Parda de Montaña breed)

Table 1. Gains of heifers from birth to first breeding according to management in the lactation and rearing periods.

LACT (0-6 months)	Low		High		SEM	*P-value*		
REAR (6-15 months)	Low (LL)	High (LH)	Low (HL)	High (HH)		*LACT*	*REAR*	*LxR*
n	7	8	7	7				
ADG 0-3 mo	0.652 [c]	0.769 [bc]	0.875 [ab]	0.909 [a]	0.04	<0.001	0.10	0.36
ADG 3-6 mo	0.649 [b]	0.653 [b]	1.228 [a]	1.239 [a]	0.04	<0.001	0.86	0.94
ADG 6-9 mo	0.538 [c]	0.996 [a]	0.433 [d]	0.865 [b]	0.04	0.002	<0.001	0.71
ADG 9-12 mo	0.912 [b]	1.092 [a]	0.710 [c]	1.087 [a]	0.03	0.004	<0.001	0.005
ADG 12-15 mo	0.835 [bc]	0.947 [a]	0.761 [c]	0.937 [ab]	0.04	0.24	<0.001	0.38
ADG LACT	0.643 [b]	0.699 [b]	1.046 [a]	1.080 [a]	0.03	<0.001	0.18	0.72
ADG REAR	0.744 [c]	0.998 [a]	0.593 [d]	0.925 [b]	0.05	<0.001	<0.001	0.10
ADG Birth-Puberty	0.680 [c]	0.863 [b]	0.833 [b]	1.085 [a]	0.02	<0.001	<0.001	0.14

LACT: lactation period; REAR: rearing period; Low: 700 g/d; High: 1000g/d
ADG = Average Daily Gain
[a,b,c,d]Means within a row with different superscripts differ (P < 0.05)

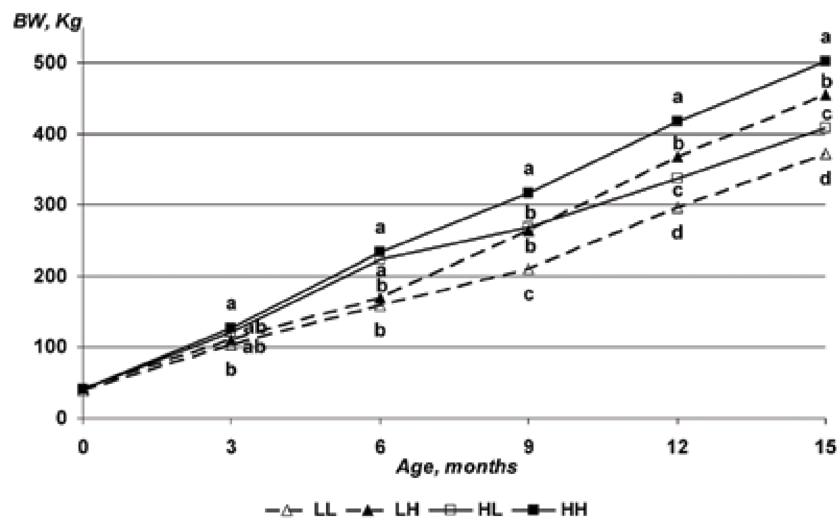

Figure 1. Weights of heifers throughout the experiment according to management in the lactation and rearing period.
L (Low gain weight = 700 g/d); H (High gain weight = 1000g/d)
[a,b,c,d]Means at a given age with different superscripts differ (P < 0.05)

Table 2. Onset of puberty and fertility rate after fixed-time artificial insemination at 15 months of age according to heifer management in the lactation and rearing periods.

LACT (0-6 months)	Low		High		SEM	P-value		
REAR (6-15 months)	Low (LL)	High (LH)	Low (HL)	High (HH)		LACT	REAR	LxR
Weight at puberty, kg	330.6	313.7	326.2	328.8	14.18	0.71	0.62	0.50
Age at puberty, mo	13.5 ^{a}	10.2 ^{bc}	11.3 ^{b}	9.2 ^{c}	0.52	0.005	<0.001	0.26
% ABW at puberty	56	54	56	56	0.02	0.75	0.56	0.53
Weight at 1st AI, kg	388.1 ^{d}	464.5 ^{b}	424.8 ^{c}	513.1 ^{a}	12.03	0.001	<0.001	0.62
Age at 1st AI, mo	15.8	15.6	15.7	15.9	5.05	0.67	0.93	0.26
Conception BW, kg	382.3 ^{d}	486.2 ^{b}	435.1 ^{c}	530.2 ^{a}	11.36	<0.001	<0.001	0.71
Conception Age, mo	15.9	16.7	16.6	16.4	0.26	0.79	0.58	0.31
nº AI	1.20	2.25	2.00	1.67	0.45	0.99	0.48	0.16
Fertility at 1st AI	4/7	2/8	4/7	3/7		0.58	0.19	
Fertility	5/7	8/8	7/7	6/7		0.58	0.50	

LACT: Lactation Period; REAR: Rearing Period; Low: 700 g/d; High: 1000g/d.
ABW: Adult Body Weight; AI: Artificial Insemination.
^{a,b,c,d}Means within a row with different superscripts differ

around 328 kg BW (Olleta *et al.*, 1991). In the same way, taken 586 kg as adult BW in Parda de Montaña (Casasús *et al.*, 2002), heifers reached puberty with 55% of adult BW as Freetly *et al.* (2011) had suggested for a wide rank of breeds.

Age at puberty is correlated with ADG from birth (Patterson *et al.*, 1992) and a marked relationship between age at puberty and previous ADG was found. Heifers reached puberty younger if their ADG from birth was higher (r=-0.77, P<0.001).

Differences found in age at puberty between treatments were due to nutrition level during lactation phase (10.3 *vs.* 11.9 m at puberty to LactH and LactL, respectively) and, in contrast to earlier works (Wiltbank et al., 1966; Gasser *et al.*, 2006), further were due to nutrition level in rearing period (9.7 *vs.* 12.4 m at puberty to LactH and LactL, respectively).

90% of heifers were pubertal 60 days before the breeding season, thus achieving one of the principal objectives in replacements heifers, they have to reach puberty 30-45 days before the breeding season (Gasser, 2013) because the fertility can be increased until 21% from first to third estrus (Perry, 2012).

Other rule of thumb in replacement heifers is that their weight should be close to 60-65% of mature BW at first service. In this case, mean weight of heifers were above 65% of mature BW (381 kg) for all treatments.

When the synchronization protocol was started three heifers from LL treatment were prepubertal, despite having apparently optimal age and weight. However, the inclusion of a progestin in the synchronization protocol, got heifers' ovulation and they became pregnant at the first insemination as Perry (2012) described.

No differences were found in fertility between treatments at the first breeding, using TAI, nor at the end of breeding season getting only three non-pregnant heifers (one of them infertile). To reach this fertility were necessary 1.85 AI per heifer. Number of AI necessary to get pregnant was not influenced by management gotten by heifers along the experiment.

It can be concluded that, depending on the food availability, heifers would be able to compensate lower growth rates in previous phases. These preliminary results would confirm the feasibility of advancing the first service from 21 to 15 months of age in beef cattle. In extensive systems, using TAI at 15 months, it will be necessary to guarantee growth rates close to 1 kg/d during lactation or/and rearing, the first option consuming less amount of concentrate. Additional research is needed to determinate if no impact on adult size and dystocia frequency are registered at first and subsequent calvings

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