Influence of age at first calving in a continuous calving season on productive, functional, and economic performance in a Blonde d'Aquitaine beef population¹

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ABSTRACT: The lifetime production of 7,655 cows with known age at first calving and a total of 27,118 parity records from 301 purebred Blonde d'Aquitaine herds were used to demonstrate the economic benefits of 2 yr of age at first calving. Ages at first calving ranged from 20 to 48 mo, and cows were divided into 5 calving groups, starting with early calving from age 20 to 27 mo up to late calving from age 40 to 48 mo. The information was gathered into 2 data sets, one for only primiparous cows and the second for all cows. The traits analyzed in this study were grouped as functional, linear type, and production traits. Functional traits were calving interval, calving ease, and number of calvings. Skeletal, muscle, and functional appraisal were included as linear type traits. The production traits studied were BW and weaning weight, carcass growth, and conformation of the offspring. The only significant traits found in primiparous cows were late age at first calving, which resulted in heavier BW calves, and early age at first calving, which resulted in calves with greater carcass conformation scores. Age at first calving was found to

be significant only in its effect on BW and the number of calvings over a cow's lifetime, with lighter calves for early age at first calving. Heritability for age at first calving was 0.17. Genetic correlation of age at first calving with direct calving ease was positive (0.27) and that with maternal calving ease was negative (−0.39). Age at first calving showed a negative genetic correlation with lifetime number of calvings (−0.29) and a positive correlation with calving interval (0.14). Correlations with production and type traits were low, except for skeletal development (−0.29). Based on phenotypic and genetic analysis, there is a tendency for early-calving cows to produce a greater lifetime number of calves with less muscle but good carcass growth. Age at first calving affected the number of heifers in the herd, replacement rate, and number of animals slaughtered each year. Shortening the age at first calving from 3 to 2 yr led to a reduction of heifer feeding cost of US\$21.24 (17.7€), a reduction of production cost of \$26.52 (22.1€), and a profit increase of \$25.80 (21.50€) per slaughtered animal per year over lifetime cow production.

Key words: age at first calving, continuous calving season, genetic correlations, profitability

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INTRODUCTION

Different studies in the literature have shown a benefit for beef production when first calving occurred between 22 and 24 mo of age, such as

a shorter interval to return of investment and an increase in the lifetime number of calves produced and, therefore, kilograms of meat produced (Morris, 1980; Day and Anderson, 1998; Day and Nogueira, 2013). Adaptation of natural feed resources to dam energy requirements is targeted at 2 yr of age at first calving (AFC) with a concentrated calving season between 2 and 4 mo. A unique calving season is recommended in temperate regions (Berry and

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Evans, 2014), mandating intensive management to obtain an AFC of 2 yr. Regions with slow-maturing breeds, less intensive management, or limited forage production force the AFC up to 3 yr of age. Reasons to delay AFC are lighter birth weight (**BW**) of calves from dams that are too young (Short et al., 1994) and fear of detriment to mature dam weight.

Early AFC is among the reproductive traits that ensure a profitable and sustainable beef production due to its relation to yearly incomes and rearing cost (Berry and Evans, 2014). Heritability of AFC is moderate in most studies (Koots et al., 1994; Gutiérrez et al., 2002; Phocas and Sapa, 2004). Berry and Evans (2014) found a higher heritability (0.31). A genetic correlation from -0.71 to -0.22 has been found between AFC and calving interval (Roughsedge et al., 2005; Berry and Evans, 2014). Roughsedge et al. (2005) estimated correlations between AFC and mature weight from -0.29 to 0.03 . Production traits as live weight at 400 d, average daily gain, and residual feed intake obtained correlations with AFC from -0.18 to -0.29 (Roughsedge et al., 2005; Crowley et al., 2011). Correlations from 0.08 to 0.45 between AFC and type traits (size and body depth) were estimated by Gutiérrez et al. (2002).

The purposes of our study were 1) to determine current average AFC in Blonde d'Aquitaine; 2) to calculate its influence on functional, type, and production traits; 3) to estimate genetic parameters for AFC and other functional, type, and production traits; and 4) to quantify the economic impact of lowering the AFC.

MATERIALS AND METHODS

Animals and Data

Data editing and trait definitions. Data from 1983 until 2015 from 7,655 cows with 27,118 calvings in 301 herds were analyzed. Reproductive performance, linear type, live weights, and carcass traits from their progeny were included in the analysis. Spanish Blonde Aquitaine is located in North of Spain mainly in Basque Country.

Reproductive performance and survival. Functional traits other than AFC considered were calving ease (**CE**), calving interval (**CI**), and number of calvings (**Nc**) as a measure of longevity. Age at first calving was measured as months from birth to first calving between 20 and 48 mo of age. Calving ease was scored at time of birth on a scale of 1 to 5, where 1 = no assistance given, 2 = slight assistance given, 3 = assistance given, 4 = a cesarean delivery, and 5 = an abnormal delivery (excluded from calculations).

Calving interval was defined as the number of days between 2 consecutive calvings, ranging from 300 to 1,035 d. First CI was defined as the number of days between the first and the second calving (also ranging from 300 to 1,035 d). Longevity was measured as Nc only for cows that had the opportunity to calve for at least 6 yr after their first calving. It must be noted that Nc may not represent the actual longevity because in this breed, adult cows can be commercialized as live animals. Data from the 7,655 cows were included in the analysis from 1983 until 2015.

Linear type traits. Linear scoring is a subjective assessment of muscle and skeletal development and functionality. For Blonde d'Aquitaine, it is assessed from 90 to 365 d of age using a single classifier accounting for condition (0 = from birth to weaning, 1 = at weaning, and 2 = after weaning). The database used in this study consisted of data on 2,649 classified animals (1,290 males and 1,358 females) from 2002 until 2015 from 27 herds that had available linear type trait data from the initial 301 herds. Calves were classified for 19 traits (Alderson, 1999; L'Institut de l'Élevage, 2017), grouped into muscle development (**MD**), skeletal development (**SKD**), and functional aptitude (**FA**) and considered type traits in this study. Skeletal development was the average classification for back length, pelvis length, hip width, and 2 times the withers height. Muscular development was the average classification for withers width, width behind withers, hind quarter development, thigh width, and 2 times the loin development. Functional aptitude was the average of classifications for forelegs, rear legs, muzzle width, and top line.

Live weights. Live weight was obtained from official records from 1995 to 2015 for weaning weight (**WW**) and BW. Weaning weight was adjusted to 210 d from the live weight of the calf from 160 to 240 d of age. For this study, data from 20,435 animals (9,922 males and 10,513 females) weighed at birth and 7,045 animals (3,494 males and 3,551 females) weighed at weaning were available from 244 and 143 herds, respectively.

Carcass traits. Price is determined using carcass weight (**CW**) and carcass conformation scores (**CCS**). Slaughterhouse records included 4,500 records (2,480 from males and 2,020 from females) of CW and CCS from animals from 10 to 17 mo of age at slaughter from 15 slaughterhouses and 108 herds from 2004 until 2015. Carcass conformation classification is based on visually assessed scores for conformation and fat classes, which are combined to form a categorical description of the carcass (SEUROP), according to the standards implemented by the 1,208/81 and 1,026/91 European Community Regulations (European Economic Community,

1981, 1991). Carcass conformation score followed the SEUROP scoring system and was converted into a linear 1 to 16 point scale. Carcass growth (CG) of slaughtered animals from 10 to 17 mo of age was defined as the ratio between CW, expressed in kilograms, and age at slaughter, expressed in days (L'Institut de l'Élevage, 2017). Carcass growth scores under 0.57 kg/d and over 1.25 kg/d were omitted.

Five groups of suckler cows were established according to AFC (20 to 27, 28 to 31, 32 to 35, 36 to 39, and 40 to 48 mo). Table 1 shows the number of records for AFC, CI, and Nc from cows and the number of calves from cows in each AFC group for CE, BW, WW, MD, SKD, FA, CG, and CCS. The data are presented for primiparous cows and for all cows over their entire lifetime. Table 2 shows the

Table 1. Number of cows, total calvings, and calving ease, birth weight and weaning weight, and carcass weight records from their progeny by age at first calving for primiparous cows and for all cows

Records	Age at first calving group, mo					Total
	20 to 27	28 to 31	32 to 35	36 to 39	40 to 48	
Cows	574	1,062	2,413	2,013	1,593	7,655
Total calvings	2,293	3,591	8,866	6,945	5,423	27,118
Calving ease records	983	2,149	5,789	4,383	3,278	16,678
Calving ease records of primiparous cows	212	594	1,533	1,187	859	4,385
Birth weighted calves ¹	1,310	2,578	6,972	5,466	4,109	20,435
Birth weighted calves of primiparous cows ¹	290	740	1,856	1,491	1,119	5,496
Weaning weighted calves ¹	368	900	2,625	1,806	1,326	7,045
Weaning weighted calves of primiparous cows ¹	82	239	698	489	362	1,870
Classified calves ¹	82	287	1,236	781	263	2,649
Classified calves of primiparous cows ¹	12	55	231	169	69	536
Slaughtered calves ¹	246	537	1,658	1,141	918	4,500
Slaughtered calves of primiparous cows ¹	46	139	409	288	230	1,112

¹Data from progeny of cows belonging to each age at first calving group.

Table 2. Phenotypic means of functionality, type, and production traits by age at first calving for primiparous cows and for entire cow lifetime and years of recording

Traits	Age at first calving group, mo				
	20 to 27	28 to 31	32 to 35	36 to 39	40 to 48
Functionality traits					
Age at first calving (AFC), mo	25.30	30.30	34.20	37.60	43.80
Calving ease (CE), ¹ 1 to 4	2.10	2.13	2.13	2.15	2.15
Calving ease of primiparous cows (CE1), ¹ 1 to 4	2.19	2.19	2.18	2.22	2.24
Calving interval (CI), d	439.30	446.90	439.40	446.30	451.90
Calving interval of primiparous cows (CI1), d	477.60	472.70	465.40	469.90	474.00
Number of calvings (Nc)	4.72	4.39	4.67	4.45	4.36
Type traits¹					
Muscle development (MD), 0 to 100	54.20	57.50	59.20	58.90	56.70
Muscle development of primiparous cows (MD1), 0 to 100	49.80	57.40	61.30	59.40	54.40
Skeletal development (SKD), 0 to 100	57.00	61.40	65.30	63.30	60.70
Skeletal development of primiparous cows (SKD1), 0 to 100	54.00	60.00	65.50	62.80	59.20
Functional aptitudes (FA), 0 to 100	57.50	58.80	58.90	59.30	59.30
Functional aptitudes of primiparous cows (FA1), 0 to 100	56.30	57.70	58.10	59.50	58.20
Production traits¹					
Birth weight (BW), kg	44.70	44.40	44.50	44.70	45.10
BW of primiparous cows (BW1), kg	43.60	42.50	42.60	43.30	43.80
Weaning weight (WW), kg	273.60	276.10	276.70	274.10	271.70
Weaning weight of primiparous cows (WW1), kg	258.20	266.70	265.10	262.00	262.00
Carcass conformation score (CCS), 1 to 16	9.08	9.44	9.45	9.60	9.601
Carcass conformation score at first calving (CCS1), 1 to 16	9.60	9.60	9.50	9.70	9.60
Carcass growth (CG), kg/d	0.88	0.88	0.88	0.89	0.89
Carcass growth of primiparous cows (CG1), kg/d	0.85	0.84	0.85	0.87	0.87

¹Data from progeny of cows belonging to each AFC group.

average for each trait for cows and their calves for primiparous cows and for all cows over their entire lifetime.

Description of management. Management is non-seasonal, but farmers tend to avoid calvings in summer and winter (Fig. 1). Around 45% of calvings took place from February to June and 28% from September to December. A smaller number of calvings took place in summer and winter. Calvings in the spring are the most common, with more than 10% in each of March, April, and May, and less than 6% in each of July, August, and December.

Statistical Analysis

Analyses for primiparous cows and all cows were performed separately for 11 traits. Mixed models were adjusted and always included herd-year as a random effect; the fixed effects included were AFC group (1 to 5), season, sex, Nc (only for analyses with all cows), condition at classification, slaughterhouse, and age of the animal as covariate. A permanent environmental effect was also considered a random effect in the analyses for all cows, to take into account the repeated measures. We used the lmerTest package (Kuznetsova et al., 2016) in R and set the statistical significance at $P < 0.05$. The least squares means of the 5 AFC groups for 11 traits were estimated using the lsmeans (Lenth, 2016) and lmerTest R packages

(Kuznetsova et al., 2016). More than 3 records per group were required for comparison of groups. Significant fixed effects considered for each trait are shown in Table 3 for primiparous cows and in Table 4 for all cows over their entire lifetime, including the percentage of variance explained by random effects.

Estimation of Economic Importance of Age at First Calving

The economic impact of the AFC was calculated using the profit function developed by López-Paredes et al. (2017). Profit (PROFa) in U.S. dollars per slaughtered young animal per year was calculated as $PROFa = c_s \times (I_s - FAT - PROD)$, in which c_s is 365/age at slaughter, I_s is income per slaughtered young animal, FAT is the average fattening cost per slaughtered young animal, and PROD is the averaged production cost per slaughtered young animal.

Income is related to CW and carcass price per kilogram determined using the SEUROP score (European Economic Community, 1981). The carcass price per kilogram depends on sex, with US\$0.36/kg (0.30€/kg) more for female carcasses than for male carcasses. The fattening cost to meet the energy requirements of an animal depends on energy requirements, age at slaughter, and the energy price per unit. Energy requirements during fattening depended on growth rate during the fattening process and were estimated according to the NRC (2000). The averaged production cost per slaughtered young animal was calculated as follows: $PROD = [(SER + HER) + p_{unf} + CER + p_{ufc} - Icc]/productivity$, in which SER is the annual energy requirement for suckler cows; HER is annual energy requirement for heifers for growth, maintenance, lactation, and pregnancy; CER is the energy requirement for fattening culled cows; p_{unf} is the price of UFL, in which UFL is a unit of energy requirement for animals in low growth, gestation, maintenance, lactation, and low growth, defined as 1,700 kcal NE; p_{ufc} is the price of UFC, in which UFC is a unit of energy requirement for animals in fattening, defined as 1,820 kcal NE; and Icc is income per culled cow sales. It was assumed that the energy price per unit (p_{unf}) is the same for heifers and cows but different for fattening culled cows (p_{ufc}). The SER and CER were calculated in accordance with the INRA (1988) and Agabriel and D'Hour (2007).

Figure 1. Calving frequency (%) per month for the Blonde d'Aquitaine population studied.

Table 3. Statistically significant fixed and random effects (*P*-value) included in the models used to determine the incidence of age at first calving (AFC) on each analyzed trait in primiparous cows

Trait ¹	Effect						
	AFC	Herd-year ²	Season	Sex	Age	Slaughterhouse	Condition at classification
CI	0.100	<0.001	<0.001	—	—	—	—
CE	0.610	<0.001	<0.001	<0.001	—	—	—
MD	0.160	<0.001	0.011	<0.001	<0.001	—	0.006
SKD	0.340	<0.001	0.910	0.250	<0.001	—	<0.001
FA	0.740	<0.001	0.110	<0.001	0.020	—	0.130
BW	<0.001	<0.001	<0.001	<0.001	—	—	—
WW	0.690	<0.001	<0.001	<0.001	<0.001	—	—
CG	0.170	<0.001	<0.001	<0.001	<0.001	0.005	—
CCS	0.016	<0.001	<0.001	<0.001	0.024	<0.001	—

¹CI = calving interval; CE = calving ease; MD = muscle development; SKD = skeletal development; FA = functional aptitudes; BW = birth weight; WW = weaning weight; CG = carcass growth; CCS = carcass conformation score.

²Herd-year was included in the models as random effect.

The HER was calculated as follows:

$$\text{HER} = \text{RR}_y \times B \times [1 + (M/2)] \times \text{HER}_d \times 365, \quad (1)$$

in which RR_y is the annual replacement rate per adult cow, B is the number of batches of contemporary heifers, M is mortality, and HER_d is average daily energy requirements per heifer from weaning to first calving. The HER_d was calculated so that the heifer reached 65% of mature weight at first service; if the AFC is less, the energy required to reach 65% of mature weight by AFC increases (Agabriel and D'Hour, 2007). Yearly replacement rate was calculated as follows:

$$\text{RR}_y \times F \times \text{RR}, \quad (2)$$

in which F is the number of calvings per cow per year and RR is the replacement rate per calving, and it was calculated as the percentage of heifers in the herd per cow and per calving. The RR depends on longevity and is expressed as the number of daughters retained per calving for replacement to maintain constant herd size, in accordance with the cow survival rate: $\text{RR} = 1/\text{Nc}$, in which Nc is the number of calvings per cow and calculated as follows:

$$\text{Nc} = [(ALC - AFC)/CI] + 1, \quad (3)$$

in which ALC is age at last calving, AFC is age at first calving, and CI is calving interval.

The number of batches of heifers in the herd was calculated as follows:

$$B = (AFC - AW)/365, \quad (4)$$

in which AFC is age at first calving and AW is age at weaning.

The productivity rate is defined as the number of slaughtered young animals per cow per year and is calculated below. It depends on fertility (F), annual replacement rate (RR_y), and calf mortality rate (CM), and it was calculated as follows:

$$\text{Productivity} = (F - \text{RR}_y) \times (1 - \text{CM}). \quad (5)$$

Table 5 shows fertility and mortality, weight and growth traits, carcass traits and prices, and management choices used to calculate the profit per slaughtered young animal in this study.

Genetic Parameters

Trait heritabilities and their genetic correlations with AFC were estimated using a bivariate analysis fitting an animal model in VCE 6.0 (Groeneveld et al., 2008). The general representation of the animal model used for each trait (AFC , CI , BW , WW , MD , SKD , FA , CCS , and CG) was as follows:

$$y = Xb + Z_a a + e, \quad (6)$$

where y is a $n \times 1$ vector of records, b denotes the effects for each model shown in Table 6, with association matrix X , a is the vector of direct animal genetic effects with association matrix Z_a , and e denotes the vector of residual (temporary environmental) effects. Herd-year was included as a random effect, and the effects included in the models were shown in Table 6. Calving interval was analyzed using a repeatability animal model that included the permanent environmental effect as a random effect.

Table 4. Statistically significant fixed and random effects (*P*-value) included in the models used to determine the incidence of age at first calving (AFC) on each analyzed trait for cows over their entire lifetime and the percentage of variance explained by random effects (herd-year and permanent environmental effect)

Trait ¹	Effect						Variance explained by random effects				
	AFC	Herd-year ²	Season	Sex	Number of calvings	Age	Slaughterhouse	Condition at classification	Permanent environmental effect ²	Percent of variance herd-year	Percent of variance permanent environmental effect
CI	0.090	<0.001	<0.001	—	<0.001	—	—	—	<0.001	16.2	3.9
CE	0.550	<0.001	<0.001	<0.001	<0.001	—	—	—	<0.001	17.2	4.8
Nc	0.030	<0.001	—	—	—	—	—	—	—	20.6	—
MD	0.170	<0.001	<0.001	<0.001	0.090	<0.001	—	<0.001	<0.001	29.8	5.2
SKD	0.760	<0.001	0.310	0.440	<0.001	<0.001	—	0.040	<0.001	27.7	4.6
FA	0.730	<0.001	0.650	<0.001	0.160	<0.001	—	0.150	<0.001	56.8	8.7
BW	<0.001	<0.001	<0.001	<0.001	<0.001	—	—	—	<0.001	40.1	8.3
WW	0.340	<0.001	0.170	<0.001	<0.001	<0.001	—	—	<0.001	25.7	6.1
CG	0.130	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	—	<0.001	21.7	6.2
CCS	0.920	<0.001	0.015	<0.001	0.040	<0.001	<0.001	—	<0.001	29.5	8.4

¹CI = calving interval; CE = calving ease; Nc = number of calvings; MD = muscle development; SKD = skeletal development; FA = functional aptitudes; BW = birth weight; WW = weaning weight; CG = carcass growth; CCS = carcass conformation score.

²Herd-year and permanent environmental effect were included in the models as random effect.

* $P < 0.05$; ** $P < 0.01$; < 0.001 $P < 0.001$.

Table 5. Fertility and mortality traits, weights and growth traits, carcass traits and prices, management choices, and supplementation prices (unit of measure) included in the profit function

Traits and conditions	Average
Fertility and mortality traits	
Mortality 0 to 48 h, %	2
Preweaning mortality, %	2
Calf mortality, %	1
Adult mortality, %	1
Calving interval, d	444
Age at last calving, yr	12
Weights and growth traits	
Male BW, kg	46.3
Female BW, kg	43.7
Male weaning weight, ¹ kg	292
Female weaning weight, ¹ kg	262
Male carcass growth, carcass kg/d	0.97
Female carcass growth, carcass kg/d	0.78
Fattened, culled cow carcass weight, kg	454
Cow mature weight, kg	650
Carcass traits and prices	
Average carcass conformation score, SEUROP classification	U ²
Average dressing carcass rate of young animal, %	57
Average carcass price of average young animal, ³ US\$/kg (€/kg)	4.752 (3.96)
Culled cow carcass price, \$/kg (€/kg)	3.63 (3.00)
Dressing carcass rate of culled cow, %	54
Management choices and prices	
Age of slaughter, d	385
Age at weaning, d	180
Fattening period of young animal length, d	205
Fattening period of culled cow length, d	120
Price of the unit of supplementation in UFL, ⁴ \$/UFL (€/UFL)	0.144 (0.12)
Price of the unit of supplementation in UFC, ⁵ \$/UFC (€/UFC)	0.300 (0.25)

¹Weaning weight at 180 d.

²Commission of the European Communities (1982).

³Price per kilogram of female carcasses was \$0.36 (0.30€) over that of male carcasses.

⁴UFL = unit of energy requirement for animals in low growth, gestation, maintenance, lactation, and low growth (1,730 kcal of NE; [Vermorel, 1978](#)).

⁵UFC = unit of energy requirement for animals in fattening (1,850 kcal of NE; [Vermorel, 1978](#)).

Calving ease was analyzed as follows:

$$y = Xb + Z_a a + Z_m m + Z_c c + e \quad (7)$$

where y is a $n \times 1$ vector of records, b denotes the fixed and random effects in the model ([Table 6](#)) with association matrix X , a is the vector of direct animal genetic effects with association matrix Z_a , m is the vector of maternal genetic effects with

association matrix Z_m , c is the vector of maternal permanent environmental effects with association matrix Z_c , and e denotes the vector of residual (temporary environmental) effects.

For AFC, only herd–year was included as a random effect in the model. Because of the small number of records with MD, SKD, and FA, BW was also included as a third trait in the analyses with AFC. The pedigree of each animal was traced back to the base population of 49,322 animals, and 12 genetic groups were established according to animal birth dates for founder animals.

RESULTS

Effects of Age at First Calving on Production, Functional, and Type Traits

Least squares means, SE, and means comparisons of studied traits related to each AFC group are shown in [Table 7](#) for primiparous cows' first calving.

For primiparous cows, only BW and CCS were significantly affected by AFC. There is a tendency toward greater BW as AFC increases, with a slight 0.5-kg difference between calves of cows with an AFC of 20 to 27 mo and calves of cows with an AFC of 40 to 48 mo, but BW of calves of cows with an AFC of 20 to 27 mo was not significantly different than that of the calves of cows in the other groups. Means of visually assessed MD, SKD, and FA for first calving calves showed no significant differences due to a high SE, perhaps because of the small number of animals classified as early AFC. Calves from early AFC cows had greater CCS values, 0.5 to 0.7 points higher than the other groups, but there was not a tendency.

[Table 8](#) shows the least squares means of studied traits for cows in all lifetime calvings. There were no differences for fertility, type, and production traits, except for BW and Nc. Birth weight was 0.6 to 0.7 kg heavier for the animals in the group with later AFC, over 40 mo. Cows with earlier AFC obtained higher number of calves, Nc was 0.4 lower with later AFC, over 40 mo compared with 20- to 27-mo and 35- to 39-mo groups.

Genetic Parameters

The heritability and genetic correlations with AFC of the traits studied are shown in [Table 9](#). Estimated heritability of AFC was moderate.

Table 6. Effects included in the models for the estimation of variance components.

	Effects									
	Herd-year ²	Season	Sex	Number of calvings	Age	Slaughterhouse	Condition at classification	Permanent environmental effect ²	Animal	Maternal effect
AFC	x	x	—	—	—	—	—	—	x	—
CI	x	x	—	x	—	—	—	x	x	—
CE	x	x	x	x	—	—	—	x	x	x
Nc	x	-	—	—	—	—	—	—	x	—
MD	x	x	x	—	x	—	x	—	x	—
SKD	x	—	—	x	x	—	x	—	x	—
FA	x	—	x	—	x	—	—	—	x	—
BW	x	x	x	x	—	—	—	—	x	—
WW	x	—	x	x	x	—	—	—	x	—
CG	x	x	x	x	x	x	—	—	x	—
CCS	x	x	x	x	x	x	—	—	x	—

¹CI = calving interval; CE = calving ease; Nc = number of calvings; MD = muscle development; SKD = skeletal development; FA = functional aptitudes; BW = birth weight; WW = weaning weight; CG = carcass growth; CCS = carcass conformation score.

²Herd-year and permanent environmental effect were included in the models as random effect.

Table 7. Least squares means ($\pm$ SE) for primiparous cows of first calving interval, calving ease, muscle development, skeletal development, functional aptitudes, BW, weaning weight, carcass growth, and carcass conformation score for each age at first calving group

Least squares means for primiparous cows	Age at first calving group, mo				
	20 to 27	28 to 31	32 to 35	36 to 39	40 to 48
Calving interval, d	479.7 $\pm$ 8.9	473.9 $\pm$ 6.2	464.8 $\pm$ 4.3	462.8 $\pm$ 4.7	463.1 $\pm$ 5.3
Calving ease, 1 to 4	2.2 $\pm$ 0.04	2.2 $\pm$ 0.03	2.2 $\pm$ 0.02	2.2 $\pm$ 0.02	2.2 $\pm$ 0.02
Muscle development, 0 to 100	51.1 $\pm$ 4.1	55.3 $\pm$ 2.7	56.6 $\pm$ 2.5	55.4 $\pm$ 2.5	56.7 $\pm$ 2.7
Skeletal development, 0 to 100	61.4 $\pm$ 3.5	58.6 $\pm$ 1.9	61.7 $\pm$ 1.3	60.7 $\pm$ 1.4	62.7 $\pm$ 1.8
Functional aptitudes, 0 to 100	56.0 $\pm$ 3.2	58.2 $\pm$ 1.6	58.6 $\pm$ 0.9	58.4 $\pm$ 1.0	57.3 $\pm$ 1.5
Birth weight, kg	43.7 $\pm$ 0.3 ^{abc}	42.9 $\pm$ 0.2 ^c	43.1 $\pm$ 0.2 ^c	43.6 $\pm$ 0.2 ^b	44.2 $\pm$ 0.2 ^a
Weaning weight, kg	275.1 $\pm$ 5.4	280.7 $\pm$ 3.5	280.0 $\pm$ 2.5	280.8 $\pm$ 2.8	284.2 $\pm$ 3.5
Carcass growth, kg/d	0.86 $\pm$ 0.02	0.86 $\pm$ 0.01	0.87 $\pm$ 0.01	0.88 $\pm$ 0.02	0.88 $\pm$ 0.01
Carcass conformation scores, 1 to 16	9.4 $\pm$ 0.3 ^a	8.9 $\pm$ 0.2 ^{ab}	8.7 $\pm$ 0.2 ^b	8.9 $\pm$ 0.2 ^{ab}	8.7 $\pm$ 0.2 ^{ab}

^{a-c}Means within a row with different superscripts differ ($P < 0.05$).

Higher heritability was found for growth traits and type traits, especially CG, followed by WW, BW, and CCS. The lowest heritability was found for the functional traits maternal CE and CI. Type traits had high heritability for MD, SKD, and FA.

Most traits showed low or moderate genetic correlations with AFC, except Nc and CE. The genetic correlation found between AFC and Nc indicated that early AFC was related to a greater Nc per cow because the cows had more opportunities to produce a calf. Furthermore, AFC was not genetically correlated with fertility (CI). Direct CE showed a positive correlation with AFC, meaning greater calving difficulty for sucklers with greater AFC. However, maternal CE showed a negative correlation with AFC; that is, later AFC was associated with greater CE. Skeletal development was negatively correlated indicating

cows with higher SKD at weaning had earlier AFC. Functional aptitudes presented moderate negative correlations with AFC. Carcass conformation score and CG were not genetically correlated with AFC and showed low genetic correlation. Estimated SE values were high, especially in production traits, perhaps owing to less data available for these traits.

Economic Impact of Age at First Calving

The influence of AFC on the number of batches of heifers (annual groups of females intended for replacement; Eq. 1), replacement rate, number of females slaughtered as young animals, and cow productivity is shown in Table 10.

An increase in AFC led to an increase in the number of batches of heifers retained on the

Table 8. Least squares means ($\pm$ SE) for cows over all lifetime calvings of calving interval, calving ease, number of calvings, muscle development, skeletal development, functional aptitudes, BW, weaning weight, carcass growth, and carcass conformation score

Least squares means for all cows	Age at first calving group, mo				
	20 to 27	28 to 31	32 to 35	36 to 39	40 to 48
Calving interval, d	449.9 $\pm$ 10.9	458.0 $\pm$ 10.7	452.1 $\pm$ 10.5	455.7 $\pm$ 10.6	456.5 $\pm$ 10.6
Calving ease, 1 to 4	2.1 $\pm$ 0.03	2.1 $\pm$ 0.02	2.1 $\pm$ 0.02	2.1 $\pm$ 0.02	2.1 $\pm$ 0.03
Number of calvings	4.8 $\pm$ 0.1 ^a	4.5 $\pm$ 0.1 ^b	4.8 $\pm$ 0.1 ^a	4.4 $\pm$ 0.1 ^b	4.4 $\pm$ 0.1 ^b
Muscle development, 0 to 100	57.6 $\pm$ 1.5	60.0 $\pm$ 1.2	60.4 $\pm$ 1.1	60.7 $\pm$ 1.1	59.7 $\pm$ 1.2
Skeletal development, 0 to 100	56.1 $\pm$ 1.5	58.7 $\pm$ 1.2	58.9 $\pm$ 1.0	59.4 $\pm$ 1.1	58.4 $\pm$ 1.2
Functional aptitudes, 0 to 100	54.7 $\pm$ 1.2	57.1 $\pm$ 0.7	57.5 $\pm$ 0.5	57.9 $\pm$ 0.6	56.8 $\pm$ 0.7
Birth weight, kg	44.8 $\pm$ 0.3 ^{bc}	44.8 $\pm$ 0.3 ^c	44.9 $\pm$ 0.3 ^{bc}	45.1 $\pm$ 0.3 ^b	45.5 $\pm$ 0.3 ^a
Weaning weight, kg	278.7 $\pm$ 4.8	278.8 $\pm$ 4.5	279.7 $\pm$ 4.3	281.1 $\pm$ 4.4	280.3 $\pm$ 4.4
Carcass growth, kg/d	0.87 $\pm$ 0.01	0.87 $\pm$ 0.01	0.86 $\pm$ 0.01	0.87 $\pm$ 0.01	0.87 $\pm$ 0.01
Carcass conformation score, 1 to 16	8.9 $\pm$ 0.18	9.0 $\pm$ 0.17	8.9 $\pm$ 0.16	9.0 $\pm$ 0.16	8.9 $\pm$ 0.17

^{a-c}Means within a row with different superscripts differ ($P < 0.05$).

Table 9. Heritability of traits, genetic correlations, and their corresponding SE regarding age at first calving (AFC)

Trait	Heritability	Genetic correlation with AFC
Age at first calving	0.17 $\pm$ 0.02	
Calving ease direct	0.13 $\pm$ 0.01	0.27 $\pm$ 0.09
Calving ease maternal	0.04 $\pm$ 0.01	-0.39 $\pm$ 0.09
Calving interval	0.02 $\pm$ 0.01	0.14 $\pm$ 0.13
Number of calvings	0.19 $\pm$ 0.03	-0.29 $\pm$ 0.11
Muscularity development	0.27 $\pm$ 0.05	0.13 $\pm$ 0.14
Skeletal development	0.34 $\pm$ 0.04	-0.29 $\pm$ 0.14
Functional aptitudes	0.35 $\pm$ 0.02	-0.16 $\pm$ 0.11
Birth weight	0.29 $\pm$ 0.02	0.15 $\pm$ 0.05
Weaning weight	0.29 $\pm$ 0.03	-0.04 $\pm$ 0.10
Carcass growth	0.42 $\pm$ 0.04	-0.05 $\pm$ 0.09
Carcass conformation score	0.24 $\pm$ 0.04	0.05 $\pm$ 0.10

farm for replacement and to fewer heifers sold per year. The number of batches required for an AFC of 20 to 27 mo was 1.5 less than the number needed for an AFC of 40 to 48 mo. For an AFC of 20 to 27 mo, only 1- and 2-yr-old heifers needed to be kept in the herd. At the fixed age of culling (12 yr), the 20- to 27-mo AFC group had 1.4 more calvings per cow than the 40- to 48-mo AFC group. Also, the replacement rate was 1.4% lower for early AFC than for late AFC. A lower AFC will increase the productivity rate by 1.4% per year due to an increase in the number of heifers sold.

The impact of these changes in terms of income, cost, and profit is shown in Table 11. Income was influenced by selling more females, and production costs were reduced by shortening nonproductive

periods and increasing the number of animals slaughtered per cow each year (productivity rate).

Lowering the AFC decreased production costs because it lowered the number of batches of heifers intended for replacement and the energy cost of the rearing period. The nonproductive period for each heifer is shortened by early AFC. In this study, daily energy requirements were greater for early-calving cows to achieve suitable size at first service. In accordance with the mature weights shown in this study, suitable weight at first insemination was around 365 kg. This weight at first service would be achieved at 16, 21, 25, 28, and 31 mo of age for the 5 different AFC groups. More females were needed, and total rearing energy requirements per slaughtered animal were greater for later AFC. The difference in heifer cost between the 2 extreme AFC groups was \$33.4 (27.8€) per slaughtered young animal per year (Table 10). Moreover, replacement rate expressed in the number of heifers intended for replacement per cow per year was 1.4% higher for late AFC, and hence, there was a decrease in productivity as expressed in the number of slaughtered young animals per cow per year. This produced fewer slaughtered young animals to share the increased cost of rearing the herd by \$42.00 (35.0€) per slaughtered young animal per year for late AFC compared with early AFC.

Age at first calving also affected incomes due to the greater number of females sold. The rate of females marketed per average young animal was greater; the price per kilogram of female carcasses was \$0.36/kg (0.30€/kg) higher than that of male carcasses, but females showed a 0.18 kg lower growth rate than males. The greater nonproductive period of the early AFC group led to a \$42.00

Table 10. Number of batches of heifers, lifetime number of calvings per cow, replacement rate, rate of slaughtered females, and productivity rate per year depending on age at first calving

Parameter	Age at first calving group, mo				
	20 to 27	28 to 31	32 to 35	36 to 39	40 to 48
Batches of heifers ¹	1.58	2.01	2.31	2.60	3.10
Estimated calvings per cow ²	9.36	9.01	8.75	8.50	8.08
Replacement rate, ³ %	9.00	9.36	9.63	9.90	10.42
Rate of slaughtered females, ⁴ %	44.66	44.48	44.28	44.12	43.81
Productivity rate, ⁵ %	72.30	71.96	71.69	71.43	70.93

¹Number of batches of heifers calculated in Eq. 4.

²Estimated calvings per cow calculated in Eq. 3.

³Percentage of heifers per cow and year calculated in Eq. 2.

⁴Percentage of females per slaughtered calf and year.

⁵Productivity in percent of slaughtered young animal per cow per year calculated in Eq. 5.

Table 11. Heifer cost, production cost, fattening cost, incomes, and profit expressed in U.S. dollars per slaughtered young animal per year by age of first calving

Economic results, US\$/slaughtered calf each year	Age at first calving, mo				
	20 to 27	28 to 31	32 to 35	36 to 39	40 to 48
Income	1,739.04	1,739.64	1,740.12	1,740.72	1,741.68
Heifer cost	28.68	37.08	43.56	49.92	62.04
Production cost	526.08	536.28	544.44	552.60	568.08
Fattening cost	948.60	948.96	949.32	949.56	950.04
Profit	264.36	254.40	246.36	238.56	223.56

(35.0€) increase in production cost per slaughtered young animal per year for the late AFC group compared with the 20- to 27-mo AFC group and a \$23.64 (19.7€) increase per slaughtered young animal per year compared with the 33- to 35-mo AFC group. When comparing the early AFC group with the late AFC group and the intermediate 32- to 35-mo AFC group, profit increased by \$40.8 (34.0€) and \$18.0 (15.0€), respectively, per slaughtered young animal per year, or a 18.2% and 10.3%, increase, respectively (Table 10).

DISCUSSION

Data used for this study represent 301 Blonde d'Aquitaine herds and indicate there is no one single AFC management possible in a continuous calving season situation. Ages at first calving ranged from 20 to 48 mo, and the number of calvings in any given month were at least 6% of the total number of calvings (Fig. 1). Breeders avoided early AFC and set AFC at around 36 mo. This is due to the possible negative impact of early AFC on lifetime cow productivity performance, with possible reduction of calves WW from heifers with AFC, more difficult calvings or shortening in age at culling of earlier AFC cows. Lifetime traits were not affected by early AFC, except BW and Nc, with greater

Nc for early AFC and no clear tendency in BW. Fertility (CI and CE) and production traits (WW, CG, CCS, MD, SKD, and FA) were not affected by AFC. Early calving, at around 24.4 mo, heightened farm profitability by \$40.8 (34.0€) per young animal slaughtered and produced 1.4% more animals sold at a price of \$1,739.04/animal (1,449.2€/animal). A similar result was obtained by Day and Anderson (1998) with seasonal calving.

Least squares means analyses showed that early AFC is related to BW, with no effect on lifetime fertility, type, or production traits up to slaughter (Tables 6 and 7). Earlier AFC increased the productive lifespan of the dam (Nc), reducing the number of replacement heifers. The adjusted mean showed that around 0.3 to 0.4 more calvings could be obtained during a cow's lifetime with earlier calving, from 20 to 27 mo, in comparison with AFC over 36 mo (Table 3). Also, the unadjusted mean showed an increase in estimated calvings per cow (Table 9). Greater lifetime calving increased profit by reducing production costs through lower heifer rearing costs and an increase in productivity or number of heifers marketed per year (Table 10). Therefore, lowering the current AFC increased the productive life of each cow through a greater Nc at a minor cost, according to Bernard et al. (1973) and

Chapman et al. (1978), who concluded that AFC of 2 yr was a satisfactory practice. Morris (1980) and Morris et al. (2000) found 0.5 calf increase in lifetime performance in yearling heifers compared with 2-yr-old heifers at first service. Day (2015) and Patterson et al. (2000) also calculated 0.7 more calves per dam. Short et al. (1994) presented a potential negative effect of AFC in subsequent calving reproductive success, but AFC did not affect either lifetime CI or lifetime CE.

Short et al. (1994) presented a potential decrease in a calf size with early AFC and light BW and WW. Also, Day (2015) observed a decrease in WW in primiparous cows but no difference thereafter. In this study, there were no differences in WW ($P = 0.69$), but there was a difference in BW, with lighter calves for early AFC (Table 6). This study also showed that AFC did not influence CG ($P = 0.17$), measured as CW/age at slaughter. There is a lack of studies that relate AFC to CG. Considering calves are slaughtered at an average of 14 mo of age, incomes are determined by CG and CCS. Those traits were not affected by early AFC, with similar CCS for the earliest AFC group considering all parities records and greater CCS in calves from primiparous cows, but without a clear tendency. Profit per slaughtered animal rises due to a production cost reduction associated with a lower AFC. Calves from early AFC cows showed a lower MD phenotype, which could indicate that animals with less MD get pregnant earlier.

The estimated heritability of 0.17 and its economic importance (López-Paredes et al., 2017) indicated that AFC should be included in a maternal/replacement index to select for improved profit. This heritability is similar to that shown by Caetano et al. (2013), Boligon et al. (2010), and Boligon and Albuquerque (2011) in Nellore cattle and less than the 0.23 reported by Goyache and Gutierrez (2001), the 0.28 reported by Minick-Bormann (2010), and the 0.31 reported by Berry and Evans (2014).

The -0.29 negative genetic correlation of AFC with Nc confirmed that there is greater life productivity with early AFC. Cows with earlier AFC had greater longevity, measured as the number of calves produced. A 0.27 direct CE genetic correlation with AFC indicates that dams with heavier calves at birth had later AFC (size/weight at calving is directly related to direct CE). The genetic correlations of direct and maternal CE of this study were higher but carried the same signs as the 0.28 and -0.22 reported by Berry and Evans (2014), probably because this work is based on data from a single, large beef breed. A -0.39 genetic correlation with

AFC indicated greater CE for later AFC. Low positive genetic correlation with CI was obtained indicating low relationship between AFC and CI. Genetic correlation between AFC and BW, WW, and CG were low: 0.15 , -0.06 , and -0.05 . These values confirm that AFC has no genetic relationship with growth traits (WW and CG). Similar values were obtained by Berry and Evans (2014), -0.08 with WW and 0.11 with CW. Genetic correlations were similar to those reported by Berry and Evans (2014). Phocas (2009) reported that muscularity was negatively correlated (-0.53 to -0.44) with calving success (% pregnancy) of the first insemination in heifers. Roughsedge et al. (2005) reported genetic correlations of muscle score with AFC in 4 breeds, with only the Limousin having a high value. The genetic correlation of AFC with other visual type traits, SKD and FA, was moderately negative (-0.29 and -0.16 , respectively), indicating that animals with greater SKD and FA at weaning had lower AFC. Berry and Evans (2014) reported genetic correlations of type traits related to SKD of 0.18 to -0.19 . Gutiérrez et al. (2002) reported a positive correlation of 0.23 between CI and AFC, which is similar to the 0.14 found in this study. The economic value of AFC is $-\$0.192/\text{d}$ ($-0.16\text{€}/\text{d}$) per young animal slaughtered (López-Paredes et al., 2017). This amounts to $-\$5.676$ (-4.73€) per young animal slaughtered per unit of additional variance of AFC (27 d) and phenotypic deviation (163 d; Table 3). This economic importance justifies the reduction of AFC and the inclusion of AFC in the breeding goal to select cows.

The results of this work support recommending lowering the AFC from the current norm of 3 yr of age. There are no negative consequences in lifetime reproductive and productive performance or negative impacts on functional or production traits. The reduction in production costs and the improvement of cow profitability justify including AFC as an objective of any improvement program. Lowering the AFC and including it in breeding goals is feasible for a large part of population because AFC is available for the entire Spanish population because all births must be reported and include the date and identification of the dam, according to Spanish regulations.

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