Original article

Genetic relationship between cyclic ovarian activity in heifers and cows and beef traits in males

Marie-Madeleine MIALON[a], Gilles RENAND[a,*],
Daniel KRAUSS[b], François MÉNISSIER[a]

[a] Station de génétique quantitative et appliquée,
Institut national de la recherche agronomique, 78352 Jouy-en-Josas Cedex, France
[b] Domaine expérimental de Galle, Institut national de la recherche agronomique,
18520 Avord, France

Abstract – Records were collected in an experimental herd over an 11-year period from purebred Charolais heifers ($n = 351$), cows ($n = 615$) and young entire bulls ($n = 383$). The objective of the study was to estimate the genetic relationship between the components of female ovarian activity (age at puberty and *postpartum anoestrus* length), their growth rate and body condition score and beef traits measured on related bulls. Two methods were used to estimate age at puberty and *postpartum anoestrus* length: the detection of oestrous behaviour and a test of cyclicity based on plasmatic progesterone assay. This study shows the existence of significant heritability estimates for the different cyclicity traits (h^2 between 0.11 and 0.38). Most of the genetic correlation coefficients between ovarian activity and growth rate of females and males are negative and favourable (r_g between -0.43 and 0.06). Cyclicity is also favourably related with body condition score in young or adult females (r_g between -0.65 and -0.22). The genetic relationship between female ovarian activity and proportion of adipose tissue in the male carcass is, however, close to zero. These results show that an antagonism between male beef traits measured in this study and female ovarian activity is unlikely to be a cause for concern in the short term.

genetic relationships / ovarian activity / beef-traits / cattle

1. INTRODUCTION

The primary objectives in French beef cattle breeding are to improve growth rate and production of lean growth. However, knowledge of genetic correlations between components of merit like female reproduction and male carcass traits is needed for optimising a multiple trait evaluation in these breeds.

* Correspondence and reprints
E-mail: Renand@dga.jouy.inra.fr

Knowledge acquired in other species or between cattle breeds have underlined the importance of these correlations within a given breed. A survey on the correlated responses from several selection experiments mainly on laboratory animals has been conducted by Scholtz and Roux [19]. From this survey, it appeared that a selection for body mass or growth rate may have an adverse effect on viability and reproductive fitness. Such a selection might give less fertile animals. In the pig, production and reproductive traits have been considered as genetically independent for a long time. In fact, some antagonism between the two groups of traits, especially between adiposity and prolificacy cannot be excluded [7]. Some authors have suggested that an increase in carcass lean content (by decreasing adiposity) may induce a deterioration in reproductive performance, because of a deterioration in the body's ability for lipid-reserve mobilisation during the gestation or the suckling period.

In cattle, the comparison of different breeds has shown a slight opposition between beef and reproductive traits. The faster-gaining breeds with large mature size do not have a very efficient reproduction. In particular, they reach puberty at later ages than do slower-gaining breeds with smaller mature size [5].

Within the French Charolais breed, a favourable genetic relationship has been revealed between the female growth rate and its ovarian cyclic activity at puberty and after calving [13,14]. This relationship was consistent with the published results of three experiments where a selection to increase the heifers' growth rate until yearling or 18 months did not have an apparent adverse effect on their age at puberty [2,15,23].

Concerning the relationship between beef and reproductive traits, very little information is available in the literature. The results of Splan *et al.* [21], complementary to the study of MacNeil *et al.* [10], did not show any relationship between age at puberty of heifers and beef traits of steers, their paternal half-sibs. These authors concluded, however, that undesirable links may exist between carcass traits of males and reproductive traits of females. In the study of Bergfeld *et al.* [3], it appeared that selection for a carcass trait such as deposition of intramuscular fat (marbling) does not have an influence on age at puberty. Heifers sired by bulls selected for high content of intramuscular fat do not reach an earlier physiological maturity, as measured by age at puberty, than heifers sired by bulls selected for lower marbling even if they actually have a higher marbling.

The objective of our study was to estimate the within breed genetic relationship between the components of female ovarian activity (age at puberty and length of *postpartum anoestrus*) and beef traits measured on entire bulls, their paternal half-sibs.

2. MATERIALS AND METHODS

2.1. Data set

This study deals with three groups of data collected from an INRA experimental herd located in Bourges (Cher) and from two stations of performance testing:

- ovarian cyclic activity measured on females at puberty or after calving;
- beef traits measured on males;
- selection index of 510 bulls, including the 60 founding sires of the experimental progeny.

2.1.1. Animals

Sires

The experimental animals, generation G_1 males and females, were sired by a sample of 60 bulls (generation G_0) chosen by divergent selection among 510 Charolais bulls that were performance tested in two stations for 5 consecutive years. The 510 bulls entered the stations at a mean age of 312 ± 14 days and were allowed to adapt to the testing regime for 8 weeks. They were then fed an equilibrated pellet diet *ad libitum* during the first 4 testing weeks. Over the last 14 weeks of the test, distribution was managed individually so as to get an expected $1500 \, \text{g} \cdot \text{d}^{-1}$ average daily gain.

During this period in the station, the bulls were weighed every 28 days for growth assessment. Feed intake was daily recorded. At the end of the test, breeding values were computed for final live weight and residual feed intake and a selection index (I_S) was used for ranking the bulls. This index was computed as (Renand, personal communication):

$$I_S = 0.426 \, I_{FW} - 0.655 \, I_{RFI}$$

where I_{FW} (final weight index) and I_{RFI} (residual feed intake index) are standardised indexes obtained from:

$$I = 100 + 20 \frac{\hat{g} - \bar{\hat{g}}}{\sigma_p}$$

with

$\hat{g}$ = predicted breeding value of a bull (contemporary comparison);
$\bar{\hat{g}}$ = mean of the predicted breeding values for one station and one year;
σ_p = phenotypic standard deviation.

In each station-year batch, 6 bulls were selected for progeny testing: three from each tail end of the distribution of the index (I_S).

Females

At the beginning of this experiment between 1985 and 1987, unrelated Charolais females (breed representative) were bought at weaning on farms in order to establish the foundation of the experimental herd (generation G_0). After rearing, 300 of these females were first mated at two years of age and subsequently over a period of seven years to the above 60 selected Charolais bulls. These matings produced 351 G_1 heifers born between 1988 and 1994, progeny of 192 G_0 dams and the 60 G_0 sires. These 351 heifers were mated at ages 2 to 5.

Males

Beef traits were measured on 383 young bulls (generation G_1) born between 1988 and 1994 from 210 G_0 dams and the 60 G_0 sires.

After weaning at 32 weeks of age, the bull calves entered the fattening station and were allowed to adapt to the testing regime over a period of 4 weeks. During the fattening period, the bulls, divided into groups of 7, were fed an equilibrated pellet diet *ad libitum* ($0.8 \text{ UFV} \cdot \text{kg}^{-1}$; UFV: feed unit for fattening animals). Limited quantities of straw were also placed at the bulls' disposal.

At the end of the individual control period, the bulls were slaughtered at either 15 or 19 months of age at the INRA centre of Theix (Puy de Dôme). The different samples and measures collected at the slaughterhouse allowed the determination of dressing percentage, the conformation and the composition of the carcasses. The carcass composition was estimated after the 6th rib had been dissected and the internal fat deposits weighed [18].

2.1.2. Traits

Age at puberty and the length of the *postpartum anoestrus* period were measured by oestrus detection and by the progesterone test as described in Mialon *et al.* [12, 14]. Females were weighed monthly and body condition score at 12 months of age and at calving was recorded on a 6-point scale, according to Agabriel *et al.* [1]: *i.e.* from the very thin (0) to the very fat (5).

The traits analysed for the females were:
- For the growing heifer: two estimates of age at puberty: age at the first observed oestrus (AFO) and age at the first positive progesterone test (AFP), body weight (BW_{12}) and body condition score (BCS_{12}) at 12 months of age.
- For the cow at calving: two *postpartum* intervals: from calving to the first observed oestrus (ICO) and from calving to the first positive progesterone test (ICP), body weight (BW_c) and body condition score (BW_c) at calving.

Beef traits of males: the traits retained in the present study were the body weight at slaughter (BWs) and the carcass fat content (FC).

The sire selection index (I_S) was also taken into account in this study.

2.2. Statistical analysis

2.2.1. Inclusion of the selection of sires

As the 60 founder sires were selected among 510 candidates, the estimation of genetic parameters may have been biased by a possible modification of additive genetic variances in comparison with an unselected population [4]. If the analysis model includes all data upon which selection decisions were based (I_S from the 510 bulls in the present study) and if all pedigree information is taken into account, the estimation of genetic parameters would be unbiased [9, 20, 22].

2.2.2. Estimation of genetic parameters

Variance and covariance components were estimated using a restricted maximum likelihood (REML) procedure applied to a multiple-trait individual animal model with missing data (some traits were only measured on some animals) using the VCE 4.0 software developed by Groeneveld [8]. Nine traits were simultaneously integrated in two successive analyses:

y_1 = sire selection index (I_S)
y_2 = age at puberty (AFO or AFP)
y_3 = body weight at 12 months (BW_{12})
y_4 = body condition score at 12 months (BCS_{12})
y_5 = *postpartum* interval (ICO or ICP)
y_6 = body weight at calving (BW_c)
y_7 = body condition score at calving (BCS_c)
y_8 = body weight at slaughter (BW_S)
y_9 = fat content in the carcass (FC).

Up to seven generations were taken into account in the pedigree of founders.

2.2.3. Models

For each group of traits, a specific animal model was used.

The sire selection index was computed for 510 bulls. The linear model describing I_S is:

$$Y_{in} = (Station \times Year)_i + a_n + e_{in}$$

where

$(Station \times Year)_i$	= interaction between 2 fixed effects: station (2 levels) and year of control (5 levels)
a_n	= random additive genetic effect of bull n
e_{in}	= random residual effect

The heifer traits were measured on the 351 G_1 heifers. The linear model describing AFO, AFP, BW_{12} and BCS_{12} is:

$$Y_{ijktn} = Year_i + Period_j + Dam\ Age_k + Twinning_t + a_n + e_{ijktn}$$

where

$Year_i$ = fixed effect of year of birth i (7 levels)
$Period_j$ = fixed effect of the period of birth j (6 levels: end of January, 4 two-week periods in February and March, early April)
$Dam\ Age_k$ = fixed effect of dam age k (3 levels: 3–4; 5–6 and 7+ years)
$Twinning_t$ = fixed effect of type of birth t (2 levels: single or twin)
a_n = random additive genetic effect of heifer n
e_{ijktn} = random residual effect.

The female traits at calving were recorded from 1988 to 1998. A total of 1 802 performances recorded from 289 G_0 and 326 G_1 cows. The average number of *postpartum* records per female was 2.9 (1 to 7). The linear model describing ICO, ICP, BW_c and BCS_c is :

$$Y_{ijdln} = Year_i + Period_j + Calving\ difficulty_d + (Lactation \times Age)_l + c_n + a_n + e_{ijdln}$$

where

$Year_i$ = fixed effect of year of calving i (11 levels)
$Period_j$ = fixed effect of the period of calving j (6 levels: end of January, 4 two-week periods in February and March, early April)
$Calving\ difficulty_d$ = fixed effect of calving difficulty score (2 levels: natural parturition, assisted or not, and caesarean delivery)
$(Lactation \times Age)_l$ = interaction between 2 fixed effects: lactation status (2 levels: suckling or not due to the loss of the calf) and age (2 levels: primiparous and multiparous)
c_n = random permanent environmental effect related to cow n
a_n = random additive genetic effect of cow n
e_{ijdln} = random residual effect.

Male traits at slaughter were recorded on 383 G_1 male progeny. The linear model describing BWs and FC is:

$$Y_{iktn} = Year_i + Dam\ Age_k + Twinning_t + a_n + Final\ age_{iktn} + e_{iktn}$$

where

$Year_i$ = fixed effect of year of birth i (7 levels)
$Dam\ Age_k$ = fixed effect of dam age k (3 levels: 3–4; 5–6 and 7+ years)

$Twinning_t$ = fixed effect of type of birth t (2 levels: single or twin)
a_n = random additive genetic effect of bull n
$Final\ age_{iktn}$ = covariate, final age
e_{ijktn} = random residual effect.

The model can be written in matrix notation:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{Za} + \mathbf{Wc} + \mathbf{e}$$

where $\mathbf{y}$ is the vector of observations sorted by animals. The dimension of $\mathbf{y}$ is $\sum_{n=1}^{N} \sum_{t=1}^{t_n} r_{nt}$ where N is the number of animals (sires, females or males) with measured traits, t_n the number of traits measured on the animal n (with $1 \leqslant t_n \leqslant 6$) and r_{nt} the number of repeated measures of the trait t on the animal n with $r_{nt} = 1$ for selection index, heifer puberty traits and male progeny beef traits and $r_{nt} \leqslant 7$ for cow calving and anoestrus traits.

$$E \begin{bmatrix} \mathbf{y} \\ \mathbf{a} \\ \mathbf{c} \\ \mathbf{e} \end{bmatrix} = \begin{bmatrix} \mathbf{X}\boldsymbol{\beta} \\ \mathbf{0} \\ \mathbf{0} \\ \mathbf{0} \end{bmatrix} \quad \text{and} \quad \text{Var} \begin{bmatrix} \mathbf{y} \\ \mathbf{a} \\ \mathbf{c} \\ \mathbf{e} \end{bmatrix} = \begin{bmatrix} \mathbf{V} & \mathbf{ZG} & \mathbf{WC} & \mathbf{R} \\ \mathbf{GZ'} & \mathbf{G} & \mathbf{0} & \mathbf{0} \\ \mathbf{CW'} & \mathbf{0} & \mathbf{C} & \mathbf{0} \\ \mathbf{R} & \mathbf{0} & \mathbf{0} & \mathbf{R} \end{bmatrix}$$

where: $\boldsymbol{\beta}$, $\mathbf{a}$, $\mathbf{c}$ and $\mathbf{e}$ are vectors of fixed effects, additive genetic effects, permanent environmental effect and residuals, respectively, and $\mathbf{X}$, $\mathbf{Z}$ and $\mathbf{W}$ are incidence matrices relating observations to the above-mentioned vectors.

$\mathbf{V} = \mathbf{ZGZ'} + \mathbf{WCW'} + \mathbf{R}$

$\mathbf{G} = \mathbf{A} \otimes \mathbf{G}_0$ where $\mathbf{A}$ is the relationship matrix and $\mathbf{G}_0$ the 9×9 genetic (co)variance matrix between the 9 traits ($\otimes$ direct product of 2 matrices).

$\mathbf{C} = \mathbf{I} \otimes \mathbf{C}_0$ where $\mathbf{I}$ is the identity matrix and $\mathbf{C}_0$ the 3×3 (co)variance matrix of permanent environment effects for the three traits measured at calving (ICO or ICP, BW_c and BCS_c).

$\mathbf{R} = \overset{N}{\underset{n=1}{\oplus}} \mathbf{R}_{0n}$ where N is the number of animals with measured traits, $\mathbf{R}_{0n}$ the (co)variance matrix of residual effects for the t_n traits measured on the animal n ($\oplus$ direct sum of matrices). There are three different types of $\mathbf{R}_{0n}$ matrices. For the 510 sires, $\mathbf{R}_{0n}$ is a 1×1 matrix. For the 640 $\mathbf{G}_0$ and $\mathbf{G}_1$ females, the size of $\mathbf{R}_{0n}$ is either 3×3 or 6×6. For the 383 $\mathbf{G}_1$ males, $\mathbf{R}_{0n}$ is a 2×2 matrix.

The VCE program allows the estimation of the variance and covariance members of $\mathbf{G}_0$, $\mathbf{C}_0$ and the three $\mathbf{R}_0$ matrices.

Heritability of the trait t was obtained as follows:

$$h_t^2 = \sigma_{a_t}^2 / \left(\sigma_{a_t}^2 + \sigma_{e_t}^2 \right) \quad \text{for the traits 1 to 4 and 8 to 9}$$

and

$$h_t^2 = \sigma_{a_t}^2 / \left(\sigma_{a_t}^2 + \sigma_{c_t}^2 + \sigma_{e_t}^2 \right) \quad \text{for the traits 5 to 7}$$

and the genetic correlation between two traits t and t' was obtained as follows:

$$r_{g_{tt'}} = \sigma_{a_{tt'}}/\sigma_{a_t}\sigma_{a_{t'}}.$$

3. RESULTS

3.1. Environmental influence

The main environmental factors influencing age at puberty and *postpartum anoestrus* were described in Mialon *et al.* [12, 14] and will not be repeated here.

The 383 bulls were slaughtered at a mean age of 514 days and a mean weight of 650 kg. The carcass fat content was 13.7% on average (Tab. I).

The slaughter age logically influenced beef traits of growing animals. The lengthening of the fattening period by 10 days induced an increase of 10.1 kg for body weight and 0.08 points for fat content. The BW_S was significantly higher (+28 kg) for single born than for twin born bulls. But the type of birth did not have any effect on carcass fat content. The age of dam influenced the beef traits of their progeny. The bulls born from younger dams (3–4 years) were significantly lighter at slaughter (−44 kg) with a higher fat content (+1 point) than bulls from older dams (7 years and more).

3.2. Genetic variability of the different traits (Tab. II)

The heritability estimates ($h^2 \pm$ s.e.) obtained in the present study, when considering the potential selection bias, were all within 1 s.e. of the previously published estimates obtained without considering this selection bias [13, 14]. The heritability of age at puberty was relatively high: $h^2 = 0.28 \pm 0.05$ for AFP and $h^2 = 0.38 \pm 0.04$ for AFO. The heritability of the length of *postpartum anoestrus* was also important when the trait was based on the progesterone test (ICP): $h^2 = 0.32 \pm 0.03$. When the length of the anoestrus period was measured by oestrus detection (ICO), the trait was less heritable: $h^2 = 0.11 \pm 0.04$.

The heritability estimates for the different body weights (BW_{12} and BW_c for the females and BW_S for the males) were equivalent and higher than 0.50.

Table I. Beef traits of bull calves ($n = 383$) as influenced by year of birth, twinning, age of dam and final age.

	Mean $\pm \sigma_p$	Source of variation			
		Year of birth	Single birth / twinning	Dam age	Final age (slope /d)
Body weight at slaughter (kg)	650 ± 54	**	+28 kg**	**	+1.01 **
Fat content in the carcass (%)	13.7 ± 2.3	**	NS	*	+0.01**

Table II. Estimates of heritabilities (±s.e.) and genetic correlations (±s.e.) between female reproductive and male carcass traits.

		Growing Heifer			Cow at Calving			Slaughtered Calf Bull	
		AFP (AFO)	BW_{12}	BCS_{12}	ICP (ICO)	BW_c	BCS_c	BW_S	FC
Age at First positive Progesterone test (at First Oestrus)	AFP (AFO)	**0.28 ± 0.05** (0.38 ± 0.04)							
Body Weight at 12 months	BW_{12}	−0.32 ± 0.09 (−0.29 ± 0.04)	**0.53 ± 0.04**						
Body Condition Score at 12 months	BCS_{12}	−0.57 ± 0.15 (−0.65 ± 0.06)	0.33 ± 0.07	**0.47 ± 0.05**					
Interval from calving to First positive Progesterone test (to First Oestrus)	ICP (ICO)	0.43 ± 0.07 (0.58 ± 0.08)	−0.20 ± 0.06 (−0.12 ± 0.08)	−0.41 ± 0.08 (−0.59 ± 0.09)	**0.32 ± 0.03** (0.11 ± 0.04)				
Body Weight at calving	BW_c	−0.37 ± 0.07 (−0.31 ± 0.03)	0.88 ± 0.02	0.33 ± 0.06	−0.26 ± 0.05 (−0.06 ± 0.08)	**0.61 ± 0.04**			
Body Condition Score at calving	BCS_c	−0.40 ± 0.11 (−0.45 ± 0.07)	−0.14 ± 0.07	0.77 ± 0.06	−0.22 ± 0.09 (−0.53 ± 0.11)	0.09 ± 0.07	**0.19 ± 0.02**		
Body Weight at slaughter	BW_S	−0.43 ± 0.11 (−0.25 ± 0.09)	0.57 ± 0.09	0.22 ± 0.10	−0.14 ± 0.10 (0.06 ± 0.14)	0.53 ± 0.07	−0.21 ± 0.10	**0.57 ± 0.03**	
Fat content in carcass	FC	0.09 ± 0.10 (0.08 ± 0.08)	0.19 ± 0.09	0.31 ± 0.10	−0.13 ± 0.08 (−0.23 ± 0.10)	−0.06 ± 0.07	0.08 ± 0.08	0.00 ± 0.08	**0.43 ± 0.04**

For body composition, the heritability estimate of BCS_{12} in heifers ($h^2 = 0.47 \pm 0.05$) was close to the estimate obtained for FC in males (0.43 ± 0.04). On the contrary, the body condition score of cows at calving was much less heritable ($h^2 = 0.19 \pm 0.02$).

3.3. Genetic relationship among growth rate and body composition in both sexes (Tab. II)

The heifer growth rate expressed by BW_{12} was highly correlated with cow weight at calving ($r_g = 0.88 \pm 0.02$). The female weights were also positively correlated with male body weight ($r_g = 0.57 \pm 0.09$ for BW_{12} and $r_g = 0.53 \pm 0.07$ for BW_c).

Body composition was measured using the same method in heifers (BCS_{12}) and cows (BCS_c). The genetic correlation between these two traits was relatively high: $r_g = 0.77 \pm 0.06$. The genetic relationship between heifer score (BCS_{12}) and male fat content (FC) was also positive but moderate ($r_g = 0.31 \pm 0.10$). The body condition score of cows was almost genetically independent of the fat content in males ($r_g = 0.08 \pm 0.08$).

3.4. Genetic relationship among growth rate, body composition and ovarian activity in females (Tab. II)

In order to clarify the presentation, we have chosen to discuss the results where the ovarian activity measure was based on the progesterone assay since it was less influenced by unidentified environmental factors [13, 14]. However, the correlations related to oestrus traits are also given in parenthesis in Table II. It should be mentioned that very close genetic correlation coefficients have been estimated between progesterone and oestrus detection measures: $r_g = 0.94$ at puberty [13] and $r_g = 0.98$ after calving [14]. There was also a significant genetic relationship ($r_g = 0.43 \pm 0.07$) between the ovarian activity of the female at puberty (AFP) and after calving (ICP) similarly to the previously published results [13, 14].

The genetic relationship between the ovarian activity measures and BW showed that a good genetic aptitude for growth until yearling or a high body weight at calving were moderately associated with an early puberty ($r_g = -0.32 \pm 0.09$) or a short *postpartum anoestrus* period ($r_g = -0.26 \pm 0.05$). Age at puberty was also markedly related with body condition score of the heifer at 12 months ($r_g = -0.57 \pm 0.15$). High body reserves at calving were only moderately associated with short *postpartum* intervals ($r_g = -0.22 \pm 0.09$). The genetic relationships between the heifer's ovarian cyclic activity (AFP) and the cow's body traits (BW_c and BCS_c) and reciprocally (ICP *vs.* BW_{12} and BCS_{12}) were all negative (from -0.20 to -0.41).

3.5. Genetic relationship among growth rate or body composition in males and ovarian activity in females (Tab. II)

The genetic relationship between growth rate in the male (BW_S) and age at puberty in the heifer (AFP or AFO) was negative: $r_g = -0.43 \pm 0.11$ with AFP and $r_g = -0.25 \pm 0.09$ with AFO, respectively. The bulls siring male calves with high growth rates would also sire female calves with an early puberty. The relationship between male body weight at slaughter and *postpartum* intervals (ICP and ICO) was not significant: $r_g = -0.14 \pm 0.10$ with ICP and $r_g = 0.06 \pm 0.14$ with ICO.

The genetic relationship between the young bull carcass composition (FC) and age at puberty of the heifer was not significant: $r_g = 0.09 \pm 0.10$ with AFP and $r_g = 0.08 \pm 0.08$ with AFO. The relationship between carcass composition and *postpartum* intervals was slightly negative: $r_g = -0.13 \pm 0.08$ with ICP and $r_g = -0.23 \pm 0.10$ with ICO.

4. DISCUSSION

The present study is based on information collected as part of a large-scale experiment aimed at quantifying the genetic relationships between beef traits and other traits of merit, like female maternal traits, in the Charolais breed. To reach a compromise between limited experimental facilities and good precision of the estimated parameters, it was necessary to optimise the choice of the founder sires. Instead of a random sampling, it appeared more efficient to make a selection of the bulls in order to increase the genetic variability of the components related to muscular growth. The genetic parameters estimated from data measured on the selected bulls progeny might however be biased because of a modification of the variability as compared to an unselected population. The bias might be more important for traits highly correlated with the selection criteria. An appropriate model including all data upon which selection decisions were based allows to avoid this bias [9,20,22]. In our situation, the parameters estimated from female data were not very different whether sire selection was taken into account or not. However, the precision of the estimated genetic parameters was increased (lower s.e.).

The heritability of age at puberty was relatively high when appreciated by age at first oestrus or age at first positive progesterone test. These results were consistent with previously published estimates [11]. The *postpartum* interval to first positive progesterone test was also a relatively heritable trait ($h^2 = 0.32$). An estimate of the same magnitude was obtained by Darwash *et al.* [6] in dairy cattle. The negative favourable relationship between female growth rate or body condition and her ovarian activity previously described by Mialon *et al.* [13,14] was confirmed in the present study. A genetic aptitude

for high growth rate or important body fat deposits is related to an efficient cyclic ovarian activity. The favourable correlation between growth rate and ovarian activity at puberty is consistent with the results from some selection experiments [2, 15, 23] where selection to improve heifer growth rate did not have any adverse effect on age at puberty. Although the estimated coefficient is only moderate, the genetic relationship between heavy weight or important body fat deposits at calving and short *postpartum anoestrus* is an original piece of information. Up to now, only phenotypic relationship has been underlined in several surveys without quantifying, however, the genetic and environmental contributions.

The most important aspect of the present study was the opportunity to quantify the genetic relationship between male beef traits and two components of the female reproduction: age at puberty and *postpartum anoestrus* length. In order to improve the productivity of beef cattle herds, it is necessary to reduce the unproductive periods in the reproductive life of a cow, *i.e.* reducing age at first calving and/or reaching the production objective of one calf per cow per year. Breed comparisons show a possible opposition between beef and reproductive traits. Selection realised in France tends to intensify the beef specialisation in the Charolais breed by breeding bulls with high muscular growth rate and low fat content. This selection of bulls, based on a selection index combining final weight and feed efficacy at the end of an individual performance-testing period, is actually efficient for improving growth and slaughter traits. The observed selection response estimated for the 60 founder sires of the present experiment was an increase of $+14$ kg in muscle weight simultaneously to a decrease of -5 kg of fat content [17].

The genetic relationship between male and female growth rate is positive with correlation coefficients higher than $+0.50$. This indicates that genetic determinism is partly common for male and female growth rate. So it is not very surprising that male growth rate and female ovarian activity were favourably correlated since this was already the case between female growth rate and her ovarian activity. The relationship of male growth capacity is more marked with age at puberty ($r_g = -0.43$) than with *postpartum anoestrus* ($r_g = -0.14$). In the study of Splan *et al.* [21], age at puberty in heifers and carcass weight in males were genetically independent ($r_g = +0.06$). The results of the present study show that a selection that aims to increase male growth rate might not have adverse consequences on *postpartum anoestrus* length in cows and even might be favourable to decrease the age at puberty of heifers.

Although age at puberty and *postpartum* interval were negatively related to the female body condition score, no significant genetic correlation was found with the male carcass composition. Certainly, this lack of relationship was a consequence of the rather poor genetic correlations found between the male

and both measures of female fatness ($r_g = +0.31$ and $r_g = +0.08$). Male fatness was measured by a partial dissection of carcasses of animals that were intensively fed in a fattening system that enhanced differences in muscle and fat deposit growth. At twelve months of age, heifer fatness was scored by manual appreciation. Heifers were fed a roughage diet in a rearing system where differences were certainly highly dependent on feed intake capacity. Fatness of cows at calving was also scored but it was no more related to growth. Differences in fatness were certainly primarily dependent to feed intake capacity of roughage, to maintenance costs or residual feed efficiency.

It appears that the appreciation of adipose tissue importance in the male, heifer or cow were three different traits more or less correlated due to the different components involved.

Although weak, these relationships between fat in the male and female are nevertheless positive. For this, it should be questioned whether an intensive selection to decrease carcass fat content of male calves might have adverse consequences on female ovarian activity. This does not seem to be the case in the present study. The genetic relationship between fat content in males and cyclic ovarian activity in the female is almost zero: slightly negative with *postpartum* interval and slightly positive with age at puberty. In the study by Splan *et al.* [21] there was also independence between age at puberty and proportion of adipose tissue in the carcass. In the same way, a selection to increase the ability to marble did not influence age at which puberty is attained in heifer progeny [3]. These results show that further selection on muscle growth capacity in a specialised beef breed does not seem to constitute a real threat for female ovarian activity. However, a limit in the decrease of fat content might be imposed by the consumers, if some sensorial meat qualities, like flavour or juiciness are influenced by the proportion of lipids in muscle.

5. CONCLUSION

This study allowed to confirm genetic parameters previously estimated. Age at puberty and length of *postpartum anoestrus* are relatively heritable traits with a mean heritability of 0.27 and are related positively. The ovarian activity of a female at a given age is also favourably related to her body weight and the amount of body fat stores.

The study of the genetic relationship between ovarian activity in females at puberty or after calving and beef traits in males shows that an antagonism between these two groups of traits is unlikely to be a cause for concern in the short term. A selection to increase growth rate of males after weaning and during fattening will have some favourable response in the reduction of anoestrus periods of the growing heifer or the suckling cow. A selection against fatty carcasses in males won't have a significant response on the ovarian activity

in females. It is, however, also necessary to make sure that beef traits in males are not unfavourably related with other breeding ability traits of the females such as fertility.

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