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Original article

Effects of the Fec^B gene on birth weight, postnatal growth rate and puberty in Booroola × Mérinos d'Arles ewe lambs

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Abstract – The effects of the presence of the Fec^B gene on birth weight, body growth rate and puberty was analyzed in 44 Fec^BFec^+ and 48 Fec^+Fec^+ Booroola × Merinos d'Arles (MA) ewe lambs and 46 MA ewe lambs. The Fec^B gene was considered as being present when the ovulation rate, determined by five laparoscopies, was, at least one time, ≥ 3. The type of birth (single vs twins) but not the presence of the Fec^B gene, affected birth weight and body growth. In spite of a transitory difference in the percentage of cycling ewes between Fec^BFec^+ and Fec^+Fec^+, the age and body weight at the first ovulation (defined by the presence of a functional corpus luteum, as plasma progesterone >1 ng·mL^{-1}, detected at weekly sampling intervals) was similar in the three genotypes (Fec^BFec^+, Fec^+Fec^+ and MA: 332.5, 334.8, 330.8 days and 34.1, 34.1, 34.9 kg, respectively). Thus, the presence of one copy of the Fec^B gene did not modify puberty. This is an important difference between the Booroola and other prolific breeds such as Romanov, Finn or D'Man, which are characterized by a clearly precocious puberty.

Booroola sheep / birth weight / body growth / puberty / ewe lamb

Résumé – **Effets du gène Fec^B sur le poids à la naissance, la croissance corporelle post-natale et la puberté chez les agnelles croisées Booroola × Mérinos d'Arles.** Les effets de la présence du gène Fec^B sur le poids à la naissance, la croissance corporelle et la puberté ont été étudiés chez 44 agnelles Fec^BFec^+, 48 Fec^+Fec^+ Booroola × Mérinos d'Arles (MA) et 46 MA. Le gène Fec^B est considéré comme présent lorsque le taux d'ovulation, mesuré au cours de 5 laparoscopies, est, au moins une fois, ≥ 3. Le type de naissance (naissance simple ou double), mais pas la présence du gène Fec^B, a affecté le poids à la naissance et la croissance corporelle. Malgré une différence transitoire

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du pourcentage de femelles cycliques entre agnelles Fec^BFec^+ et Fec+Fec+, l'âge et le poids à la première ovulation (déterminée par la présence d'un corps jaune fonctionnel, observé quand le taux de progestérone plasmatique est >1 ng·mL^{-1}, détecté par prélèvements sanguins hebdomadaires) ont été similaires chez les trois génotypes (Fec^BFec^+, Fec^+Fec^+ et MA : 332,5, 334,8, 330,8 jours et 34,1, 34,1, 34,9 kg, respectivement). Ainsi, la présence d'une copie du gène Fec^B ne modifie pas l'âge à la puberté. Ceci constitue une différence importante entre la race Booroola et d'autres races prolifiques comme les Romanov, Finnoise ou D'Man, lesquelles se caractérisent par une nette précocité pubertaire.

Booroola / poids de naissance / croissance corporelle / puberté / agnelles

1. INTRODUCTION

The high ovulation rate and prolificacy of Booroola Merino sheep is due to a limited number of strictly linked genes or by a single autosomal gene [9, 20]. This gene is now called the Fec^B gene [21]. Since prolificacy is one of the important parameters which has an impact on the economic results of the sheep industry, the effects of the presence of one or two copies of the Fec^B gene have been studied not only on reproductive physiology or genetics, but also on production traits and management in numerous countries [27]. However, the impact of the presence of the Fec^B gene on birth weight, postnatal growth rate and age or weight at puberty in female animals is poorly documented. Indeed, contradictory results concerning birth weight in Fec^BFec^+ or Fec^BFec^B females have been reported [14, 19, 24], possibly because the effects due to litter size and/or the presence of the Fec^B gene have not always been clearly identified.

Thus, the aim of the present paper was to study the effect of the presence of one copy of the Fec^B gene on birth body weight, postnatal growth rate and age and weight at puberty in Booroola × Mérinos d'Arles females, Mérinos d'Arles being one of the two French breeds where the process of introgression of the Fec^B gene was realized [27]. Particular attention was paid to try to distinguish between the pleiotropic effect of the Fec^B gene from that of the litter size or period of birth.

2. MATERIALS AND METHODS

2.1. Location

The experiments took place in an ENSAM Experimental Station (latitude of 43° 60' North, longitude of 5° East), situated in the south part of France near Salon de Provence.

2.2. Animals

Ninety-two ewe lambs issued from three (Fec^BFec^+) Booroola rams and 46 Mérinos d'Arles (MA) control ewe lambs issued from MA non-prolific rams were studied. Their MA mothers, chosen at random from the different available families, were inseminated 54 ± 2 hours after fluorogestone acetate and equine choriogonadotrophin (500 IU) treatment [8].

Parturition was synchronized by an I.M. injection of 12 mg of dexamethaxone at day 145 of gestation [5]. During the previous month and the subsequent month of parturition the mothers were fed on natural pasture for 6 hours in the afternoon. In the morning, the ewes remained in the pen and they ate wheat straw (ad libitum) and 300 g of whole wheat grain each until 30 days after parturition, after that they were put out to pasture all day.

There was no difference between the breeds in the rams' body weight (82.5 and 80.0 kg for Merinos d'Arles and Booroola, respectively).

Table I. The effects of genotype, birth type (size) and genotype × birth type interaction on birth weight and ADG.

	Single born ewe lambs			Twin born ewe lambs			*P*-value			SEM
	Fec^BFec^+ (24)	Fec^+Fec^+ (22)	MA (12)	Fec^BFec^+ (24)	Fec^+Fec^+ (22)	MA (12)	Gen	Size	Gen × Size	
Birth weight, kg	3.9	3.9	3.7	3.2	3.2	3.0	NS	0.01	NS	0.72
ADG (0–30 d), g	215	218	212	176	172	179	NS	0.04	NS	61.0
ADG (31–70 d), g	172	165	181	150	156	142	NS	0.035	NS	55.0

MA: Merinos d'Arles; ADG: average daily gain; NS: non significant ($P > 0.05$); Gen: genotype; Size: birth type; Gen × Size: interaction between genotype and birth type; SEM: standard error of the mean.

Each ewe lamb was weighed immediately after birth, including during the night, and then every 15 days until ten weeks of age. The mother's body condition was measured the day before parturition to the nearest 0.25 point according to the technique of Jefferies [15].

Puberty achievement was defined by the presence of a functional corpus luteum, detected by a peripheral blood concentration of progesterone equal or higher than 1.0 ng of progesterone per mL of plasma [2]. All the ewe lambs studied were subjected to blood sampling at the age of 8.5 months and then, every week from 9 months until 12 months. The ewe lambs were isolated from rams in order to avoid the effects of sexual stimulation on puberty.

The presence of the Fec^B gene was defined according to Piper and Bindon [20] and Davis et al. [9]. The ovulation rates were determined endoscopically by two series of observations made at one and two years of age (3 and 2 observations, respectively).

2.3. Statistical analyses

Analyses of variance for linear models were used in order to describe the effects of known factors on average daily gain (ADG) and puberty.

$$Y = \mu + GENi + SIZEj + GEN \times SIZEij + a\,MBC + bBW + \epsilon$$

where: GEN is the genotype of the ith ewe lamb; SIZE is the litter size of the jth ewe lamb; GEN × SIZE is the interaction between GEN and SIZE; MBC is the mother body condition; BW is the birth weight and ϵ is the error. All analyses were computed using the GLM or FREQ procedures of the SAS (2001) System for Linear Models. The significance level was considered for values of $P \leq 0.05$.

3. RESULTS

3.1. Birth weight and growth rate

Birth type (litter size) induced a lower body weight (BW) at birth. Zero to 30 days average daily gain (ADG) of the Booroola × MA ewe lambs, were 210–220 g for the single born and 170–180 g for the twin born ewe lambs. During the second growth phase (30–70 days of age) ADG were 160–180 g and 140–160 g for the single and twin born ewe lambs, respectively. Live weight and ADG did not depend on the genotype effects (Tab. I).

3.2. Puberty

Puberty was achieved around 330 days of age whatever the genotype (Tab. II). Puberty has also been defined at the level of the herd, as the age where 50% of the females are in ovarian activity [11]. According

Table II. Age and body weight at puberty (means ± SEM).

Birth type		Age (days)			Body weight (kg)		
		Fec^B Fec^+	Fec^+ Fec^+	MA	Fec^B Fec^+	Fec^+ Fec^+	MA
Single born	n	20	26	34			
		328.0a	337.4a	331.1a	35.5a	35.6a	34.9a
		(32.8)	(22.8)	(24.9)	(2.8)	(3.4)	(4.8)
Twin born	n	24	22	12			
		336.3a	331.7a	324.4a	32.9b	32.3b	34.9a
		(26.1)	(32.6)	(29.8)	(3.0)	(3.7)	(3.1)

a, b: Means with different letters correspond to significant differences between birth type ($P < 0.01$); MA: Merinos d'Arles; SEM: standard error of the mean.

Table III. Evolution of the percentage of cycling ewe lambs.

Age (month)	Cycling ewes (%)		
	Fec^BFec^+ (n = 44)	Fec^+ Fec^+ (n = 48)	MA (n = 46)
8.5	11.4	4.2	8.7
9.5	13.6	4.2	15.2
10.0	22.7a	10.4b	34.8a
10.5	40.9	39.6	43.5
11.5	95.5	90.9	89.1
12.0	100.0	95.5	93.5

a, b: Means with different letters correspond to significant differences between genotypes ($P < 0.05$). MA: Merinos d'Arles.

to this definition, puberty was achieved around eleven months of age whatever the genotype (Tab. III).

Puberty, defined at the individual level, was reached at the same BW whatever the genotype (34.1, 34.1 and 34.9 kg for Fec^BFec^+, Fec^+Fec^+ and MA females, respectively, Tab. II). A 3.0 kg difference was noted according to the birth type, the twin born being lighter than the single born Booroola females (Tab. II).

The Fec^BFec^+ ewe lamb tended to achieve puberty more rapidly than the Fec^+ Fec^+ ewe lamb until 10 months of age, but the difference was only significant at 10 months of age (Tab. III, $P < 0.05$). Furthermore, after 10.5 months of age there was no more difference between the genotypes, thus the difference observed between the Fec^BFec^+ and Fec^+Fec^+ ewe (22.7 vs. 10.4%, respectively) could be considered as transitory.

4. DISCUSSION

The data present on birth BW in Merinos d'Arles, whatever the birth type, are identical to those observed by Prud'hon [22] in the same breed over a nine year observation. In our experimental conditions, the presence of one copy of the Fec^B gene was not associated with changes of birth BW. Similar data have been reported by Bodin et al. [4], Montgomery et al. [19] and Isaacs et al. [14] concerning the absence of an effect of either one or two copies of the Fec^B gene. By contrast, Smith et al. [24] have shown that one copy of the Fec^B gene was associated with lighter BW between 75 and 135 days of gestation, suggesting that birth BW could also be decreased. However, it is likely that, at least for those ages, these differences were accounted for by litter size. Indeed, a significant association between

BW and litter size was observed and 90 day old female fetuses obtained by embryo transfer and that were carriers or non carriers of the Fec^B gene had similar litter size and BW [24].

Another important feature of the present data is the absence of the effect of the presence of the Fec^B gene on postnatal body growth rate and 10 weeks BW. These results, obtained with a high number of animals, confirmed those observed in Booroola × Merino ewe lambs by Bindon, Piper and Curtis (cited in [21]). They also confirmed and extended to the other gender the data obtained by Seck [23]. Similarly, with 8 animals per genotype, Montgomery et al. [19] observed that the Fec^BFec^B ram lambs, born as singles following embryo transfer, grow more rapidly up to weaning (11 weeks), but without a significant difference at that age. Conversely, after weaning, a period not studied herein, the tendency was reversed up to 64 weeks of age, with a nearly 5 kg non significant difference at that time.

Thus, it appears that the presence of the Fec^B gene has no negative effects on the growth traits studied. Similar results were found by Seck [23] in Booroola × MA male lambs; the introduction of the prolific Fec^B gene into the Merino d'Arles breed did not appear to affect growth traits in this breed.

Puberty appeared later in the animals born in the first group. Body weight per se is not a primary cue for puberty in sheep [25], but a minimum body weight is necessary to reach puberty [13]. When an ewe lamb presents the critical weight (around 30 kg in Mérinos d'Arles), it is the photoperiod which plays the principal role on the achievement of cycling activity. It is well known that an alternation of long days after short days induces puberty [12, 26, 28] if nutritional conditions are adequate [1, 12].

The presence of the Fec^B gene was not observed to modify the age at puberty. These results confirmed those of Bindon et al., Meyer, Kelly et al., and Cleverdon et Hart, who evidenced very little [3] or no difference in age at puberty or BW at puberty when comparing Booroola females with other non prolific genotypes [7, 16, 18]. Similarly, Isaacs et al. [14] found no difference of age at puberty between Fec^BFec^B and Fec^+ Fec^+ ewes. However, a birth type effect cannot be excluded in their experiment, as clearly found in our data. Finally, as found in [14], a small percentage of females (6–10%) not linked to the presence of the Fec^B gene, remained anovulatory. Thus, the Booroola gene did not seem to express a particular precocity and this would be an important difference between Booroola sheep and the other prolific genotypes such as Romanov, Finn or D'Man, that are characterized by a clear pubertal precocity [6, 10, 17].

In conclusion, our data show that the presence of one copy of the Fec^B gene is not associated with changes in birth BW, postnatal growth rate, age or BW at puberty. Conversely, birth type significantly affected birth BW, ADG and age or BW at puberty.

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