Theriogenology 96 (2017) 58–68

Contents lists available at ScienceDirect

Theriogenology

journal homepage: www.theriojournal.com

Effect of breed, plane of nutrition and age on growth, scrotal development, metabolite concentrations and on systemic gonadotropin and testosterone concentrations following a GnRH challenge in young dairy bulls

C.J. Byrne [a, b], S. Fair [c], A.M. English [a, c], C. Urh [d], H. Sauerwein [d], M.A. Crowe [e], P. Lonergan [b], D.A. Kenny [a, *]

[a] Animal and Bioscience Research Department, Teagasc Grange, Dunsany, Co. Meath, Ireland
[b] School of Agriculture and Food Science, University College Dublin, Belfield, Dublin 4, Ireland
[c] Laboratory of Animal Reproduction, Department of Biological Sciences, University of Limerick, Limerick, Ireland
[d] Institute for Animal Science, Physiology and Hygiene Unit, University of Bonn, Bonn, Germany
[e] School of Veterinary Medicine, University College Dublin, Belfield, Dublin 4, Ireland

A R T I C L E I N F O

Article history:
Received 11 November 2016
Received in revised form
8 March 2017
Accepted 1 April 2017
Available online 3 April 2017

Keywords:
Calf-hood nutrition
Puberty
Insulin
IGF-1
Hypothalamus
Endocrinology

A B S T R A C T

The onset of puberty in the bull is regulated by the timing of early GnRH pulsatility release from the hypothalamus, which has been demonstrated to be affected by plane of nutrition during calf-hood. The aim of this study was to determine the effect of plane of nutrition on growth rate, scrotal development, metabolite concentrations and exogenous gonadotrophin (GnRH) induced release of luteinizing hormone (LH), follicle stimulating hormone (FSH) and testosterone (TT) in pre-pubertal bulls of two contrasting dairy breeds. Holstein-Friesian and Jersey bull calves were assigned to either a high or low plane of nutrition from 3 to 49 weeks of age. Intensive blood sampling was conducted at 16, 24 and 32 weeks of age, every 15 min from 30 min prior to intravenous administration of exogenous GnRH to 135 min after. Monthly blood samples were also collected and analyzed for insulin like growth factor 1 (IGF-1), insulin, leptin, adiponectin and metabolite concentration. Insulin and IGF-1 were higher in bulls on a high plane of nutrition ($P < 0.001$) but were not affected by breed ($P > 0.05$). Leptin was not affected by plane of nutrition or breed ($P > 0.05$). Adiponectin tended to be higher in bulls on a high plane of nutrition ($P = 0.05$), but was not affected by breed ($P > 0.05$). Bulls on a high plane of nutrition had a greater concentration of LH in response to GnRH ($P < 0.05$) but there was no effect of breed ($P > 0.05$). FSH concentration was not influenced by breed or plane of nutrition but FSH concentrations did decrease with age ($P < 0.01$), while, LH was not affected by age ($P > 0.05$). Jersey bulls, particularly those on a high plane of nutrition, had higher TT production in the pre-pubertal period ($P < 0.001$). Using 28 cm as a proxy for age at puberty, bulls on a high plane of nutrition were predicted to reach puberty earlier than bulls on a low plane. In conclusion, the data clearly demonstrate that a high plane of nutrition positively affects several key nutritional and reproductive hormones which are critical to the endocrinological functionality of the hypothalamic-pituitary-testicular axis in dairy-bred bull calves.

1. Introduction

The advent of genomically-assisted selection has facilitated the early identification of elite sires within weeks of birth leading to an increased demand for their semen at a young age. This necessitates that bulls reach puberty as early as possible and produce an adequate volume of high quality semen to meet this demand. It is well established that a number of factors including breed and nutritional status may influence the timing of puberty in farm animals [1]. Management factors such as nutrition can be used to hasten the onset of puberty [2] and sexual maturation in the bull [3], leading to an earlier availability of semen from these genetically

* Corresponding author.
E-mail address: david.kenny@teagasc.ie (D.A. Kenny).

http://dx.doi.org/10.1016/j.theriogenology.2017.04.002
0093-691X/

elite sires which are in high demand. The timing of the early transient rise in anterior pituitary luteinizing hormone (LH) pulsatile activity is a critical factor in determining the age at which sexual maturity is reached [4]. This early rise has been reported to occur between weeks 10 and 18 of age in Angus and Angus x Charolais bull calves [5] and is thought to induce responsiveness of testicular Leydig cells to LH, leading to an increase in testosterone (TT) production [6]. This increase in TT is necessary for the differentiation of Sertoli cells and initiation of spermatogenesis [6]. The timing and magnitude of this early LH rise has been shown to be controlled by the metabolic status of the animal [7,8].

The effect of early life plane of nutrition on sexual development in beef bulls has been demonstrated in two related studies [7,8] in which bulls offered a low plane of nutrition from 10 weeks of age experienced a delay in the onset of puberty compared to those offered either a medium or high plane of nutrition. This delay was associated with lower TT concentrations during the peri-pubertal period. These studies demonstrate that testicular size in mature animals is positively influenced by increased systemic FSH, TT and particularly LH in early life. Other authors concluded that daily gains of greater than 1.2 kg/day during calf-hood should be targeted to ensure earlier attainment of puberty in bulls [9]. More recently, a higher plane of nutrition led to a greater scrotal circumference (SC) and thus hastened age at puberty in Holstein-Friesian bulls [10]. It has also been suggested that SC can be used as a predictor of sperm output potential in young dairy bulls [11]. The effect of pre-pubertal growth rate relative to estimated mature weight on the age at onset of puberty has been documented for Simmental, Angus and Hereford heifers [12,13]. A high plane of nutrition has also been used to achieve a heavier weight, at a younger age in heifers, leading to an associated decrease of approximately four months in age at puberty [14]. Research on age at puberty onset in beef-bred bulls has also shown that early maturing breeds attain puberty at a younger age than late-maturing breeds [4]. While the effect of breed type (early v late maturing) on age at onset of puberty has been well defined in heifers; there has been less work carried out, however, in bulls, possibly due to the greater challenge involved in assessing attainment of puberty.

Metabolic hormones such as leptin, adiponectin, insulin and insulin-like growth factor-1 (IGF-1) signal the nutritional status of the animal to the hypothalamus via receptors in the arcuate, neuropeptide Y and pro-opiomelanocortin nuclei [15], which regulates the secretion of LH and FSH, mediated through the action of gonadotrophin releasing hormone (GnRH). These hormones are necessary for testicular and sexual development and in turn dictate the age at which puberty is attained [16–18]. Systemic concentrations of metabolic hormones such as IGF-1 have been shown to vary according to breed [19] and higher IGF-1 was consistent with greater LH pulsatility in Angus heifers, leading to more precocious puberty, when compared to other breeds. Additionally, IGF-1 concentrations were higher in Holstein-Friesian bulls offered a high plane of nutrition up to 31 weeks of age [10]. The influence of other metabolic hormones such as leptin on the functional development of the hypothalamic-pituitary-gonadal axis is not as clear [20,21]. We hypothesized that increasing the plane of nutrition offered to bull calves of different breeds would positively influence metabolic hormones associated with increasing secretion of reproductive hormones. Due to a lower mature bodyweight we also hypothesized that Jersey bulls would have an earlier response to plane of nutrition than Holstein-Friesians.

The aim of this study was to determine the effect of age, breed and plane of nutrition on systemic growth rate, scrotal development, metabolite concentrations, as well as exogenous GnRH-induced release of LH, FSH and TT in pre-pubertal Holstein-Friesian and Jersey bulls.

2. Materials and methods

All animal procedures performed in this study were conducted under experimental licence from the Irish Department of Health and Children (licence number B100/4516). Protocols were developed in accordance with the Cruelty to Animals Act (Ireland 1876, as amended by European Communities regulations 2002 and 2005) and the European Community Directive 86/609/EC.

2.1. Animals and treatments

Holstein-Friesian (F) and Jersey (J) bull calves ($n = 34$) with a mean ($\pm$S.D.) age of 21 ($\pm$10.3) days and bodyweight of 47.4 ($\pm$13.0) kg and 33.1 ($\pm$5.13) kg, respectively, were sourced from commercial dairy farms and were blocked on breed, age, sire and bodyweight and assigned to either a high or low plane of nutrition. All calves were group housed indoors at Teagasc, Grange Beef Research Centre on sawdust-floored pens (balanced for treatment and breed) with a space allowance of 1.6 m^2/calf. Calves were individually fed milk replacer and concentrate (Table 1) using an electronic feeding system (Förster-Technik, Vario, Engen, Germany). After five days acclimatization, at 26 ($\pm$10.3) days of age, high F ($n = 9$) and high J ($n = 8$) received 1200 g (8 L at 150 g/L) and 800 g (6 L at 133.33 g/L) of milk replacer (23% crude protein, 18% lipid; Blossom Easymix; Volac, Co. Cavan, Ireland) daily, respectively, together with concentrate *ad libitum* (Lakeland Dairies, Monaghan, Ireland). Low F ($n = 11$) were allocated 500 g (4 L at 125 g/L) of milk replacer plus a maximum of 1 kg of concentrates daily while low J ($n = 6$) were allocated 350 g (3.5 L at 100 g/L) of milk replacer plus a maximum of 1 kg of concentrates daily. Treatment diets were designed using National Research Council (2001) guidelines [22]. Bulls were weaned when consuming a minimum of 1 kg of concentrate for 3 consecutive days, at a mean age ($\pm$S.D.) of 83 ($\pm$10.5) days. Following weaning, high F and high J were offered *ad libitum* concentrates, while low F received 1.7 kg and low J received 1.4 kg of concentrate daily. All bulls had daily access to approximately 0.5 kg of straw each from pre-weaning to turn-out. This equates to F calves on the low plane of nutrition being offered 1.26 times the metabolisable energy requirements required for maintenance (ME_m) requirements and J calves on the low plane of nutrition being offered 1.17 $\times$ ME_m requirements. Bulls were turned out to grass at 16 weeks of age where high F and high J received grass and concentrate *ad libitum* while low F and low J both received grass *ad libitum* plus 0.5 kg of concentrates per day. All animals had constant access to fresh water. Bulls were weighed weekly until weaning and were weighed at 14 day intervals thereafter (Fig. 1). Scrotal

Table 1
Ingredient and chemical composition of concentrate offered to calves.

Ingredient (%)	Concentrate
Barley	26.5
Soya Bean (dehulled)	25
Maize	15
Beet pulp	12.5
Soya hulls	12.5
Molasses	5
Minerals and Vitamins	2.5
Vegetable oil	1
DM	91.2
Energy (MJ ME/kg DM)[a]	11.06
Crude Protein (g/kg DM)[b]	188
Crude Fiber (g/kg DM)	80
Ash (g/kg DM)	71
Crude oil (g/kg DM)	33

[a] Megajoules of metabolisable energy per kilogram of dry matter.
[b] Grams per kilogram of dry matter.