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Effects of a high carbohydrate diet and arginine supplementation during the rearing period of gilts on osteochondrosis prevalence at slaughter

D.B. de Koning[a,*,1], B.F.A. Laurenssen[a], R.E. Koopmanschap[a], E.M. van Grevenhof[b], P.R. van Weeren[c], W. Hazeleger[a], B. Kemp[a]

[a] Adaptation Physiology Group, Department of Animal Sciences, Wageningen University and Research Center, PO box 338, 6700 AH Wageningen, The Netherlands

[b] Animal Breeding and Genomics Center, Department of Animal Sciences, Wageningen University and Research Center, PO box 338, 6700 AH Wageningen, The Netherlands

[c] Faculty of Veterinary Medicine, Utrecht University, Department of Equine Sciences, PO box 80.153, 3508 TD Utrecht, The Netherlands

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ABSTRACT

Osteochondrosis (OC) is a consequence of necrotic growth cartilage formation early in life and suggested to be associated with lameness and premature culling of sows. Higher insulin, glucose, and insulin-like growth factor-1 (IGF-1) are associated with increased OC in horses and are affected by carbohydrates. If dietary composition can affect OC through metabolic parameters in sows, it could be a tool in practice to reduce OC prevalence. This study examined if OC prevalence in rearing gilts can be influenced by dietary carbohydrates and/or arginine by affecting IGF-1, insulin, glucose, and nitric oxide (NO) levels. Gilts (n=212; Dutch Large White x Dutch Landrace) were acquired after weaning (4 weeks of age). At 6 weeks of age, gilts were subjected to a 2×2 factorial treatment design of dietary carbohydrate and arginine level scale fed at pen level. Carbohydrate level consisted of 12.5% cornstarch and 12.5% dextrose added to a basal diet (C+) versus an isocaloric diet in which cornstarch and dextrose were replaced with 8.9% soya bean oil (C−). Arginine supplementation consisted of 0.8% arginine supplemented to a basal diet (A+) versus 1.64% alanine as the isonitrogenous control (A−). At 24 weeks of age, blood samples of in total 34 gilts around feeding were taken and assessed for insulin, glucose, IGF-1, and NO levels. After slaughter at 25 weeks of age, OC was scored on the elbow, knee, and hock joints. Gilts in the C− treatment had higher glucose and insulin levels 90 min after feeding onwards and higher IGF-1 levels than gilts in the C+ treatment ($P<0.05$). Arginine supplementation did not significantly affect metabolic parameters. Arginine supplementation tended to decrease OC prevalence ($P=0.07$) at the animal level (all joints combined) and in the knee joint. Carbohydrate treatment affected prevalence of OC only in the knee joint in which gilts in the C− treatment had a higher odds ratio (OR) to have OC (OR=2.05, CI: 1.18–3.58) than gilts in the C+ treatment. Additionally, body weight at slaughter was significant when added to the statistical model ($P<0.01$) in the knee joint and the animal level (per 10 kg increase OR=1.33, CI=1.11–1.6 and OR=1.17, CI=1.05–1.31, respectively). This study found effects of carbohydrates on OC prevalence in gilts at slaughter. The dietary treatment effects found in the current study likely have been mediated through effects on body weight.

1. Introduction

Formation of necrotic cartilage due to vascular disruption at young age in the epiphyseal growth cartilage is the first step in osteochondrosis (OC) development and suggested as a cause of lameness and premature culling in sows (Yazdi et al., 2000; de Koning et al., 2015). Reparative attempts by chondrocytes and vasculature have been suggested to occur (Ytrehus et al., 2004a; Olstad et al., 2007). Feeding practices may affect OC prevalence in sows by affecting chondrocyte functioning or growth.

Diets differing in carbohydrate content could influence OC through metabolic parameters such as glucose, insulin, and insulin-like growth factor-1 (IGF-1) as shown in horses (Ralston, 1996; Sloet van Oldruitenborgh-Oosterbaan et al., 1999; Pagan, 2001). Insulin and

* Corresponding author.
E-mail address: danny.dekoning@wur.nl (D.B. de Koning).
[1] Current address: Adaptation Physiology Group, Department of Animal Sciences, Wageningen University and Research center, 6708 WD Wageningen, The Netherlands.

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IGF-1 affect survival and proliferation of chondrocytes (Hunziker et al., 1994; Henson et al., 1997) and are involved in growth (Balage et al., 2001; Laron, 2001). Arginine through nitric oxide synthase is a nitric oxide precursor, which has been indicated as an angiogenesis signal in hypoxic tissues through its required interaction with vascular endothelial growth factor (Murohara et al., 1998; Duan et al., 2000; Dulak et al., 2000; Milkiewicz et al., 2005; Hazeleger et al., 2007; Liu et al., 2012; Wu et al., 2012). Considering that OC involves local hypoxia and that reparative responses to OC involve proliferation of chondrocytes and vasculature towards the necrotic cartilage, hypothetically, insulin, IGF-1, and arginine may aid in reparative responses of chondrocytes and vasculature to OC. However, insulin and IGF-1 can increase growth and body weight (BW) gain that in turn can increase OC prevalence (de Koning et al., 2013). Carbohydrate rich diets affect metabolic parameters such as glucose and insulin and is correlated with IGF-1 in pigs (Wientjes et al., 2012, 2013). It may be possible that both a carbohydrate rich diet and supplementation with arginine affect the prevalence of OC, where arginine supplementation could aid reparative responses and reduce OC prevalence, and carbohydrates may aid reparative responses reducing OC prevalence or increase growth and thereby increasing OC prevalence.

The aim of the study was to assess if increased dietary carbohydrate and arginine levels in the rearing period of breeding gilts decrease OC prevalence at 6 months of age. If OC prevalence is affected, this could be used as a dietary strategy to reduce OC prevalence in practice.

2. Materials and methods

2.1. Ethical note

Osteochondrosis can cause lameness affecting welfare of the gilts. Gilts were daily inspected for impairments of welfare. Severely lame or wounded gilts were taken out of the experiment and euthanized. The experiment and all measurements were approved by the Animal Welfare Committee of Wageningen University and Research center in compliance with Dutch law on animal experimentation.

2.2. Animals

The experiment was performed using 212 Topigs 20 (Dutch Large White x Dutch Landrace) gilts acquired after weaning at 27 (2.6 SD) days of age and 7.0 (1.5 SD) kg of BW from a commercial breeding company (TOPIGS, Veldhuizen Wehl, Wehl, The Netherlands). Previous research showed an OC prevalence within this line of animals of up to 60% at approximately 6 months of age (de Koning et al., 2013, 2014). Gilts were housed in a 8.37 m^2 pen with a conventional floor consisting of 60% slatted floor (twisted metal bars) and 40% solid floor (epoxy-coated concrete). Enrichment items were provided at all times (such as biting chains, burlap sacks, solid plastic balls, rubber mats) and different items were made available within pens every 2–3 days. Gilts were weighed every 2 weeks after weaning until slaughter at on average 176 (4.4 SD) days of age. Gilts had continuous access to water through a drinking nipple. For approximately the first 2 weeks after weaning, all gilts received a similar commercial weaning diet administered ad libitum to adapt to housing conditions after weaning.

2.3. Treatments

Gilts were assigned to 1 of 4 treatment groups and 1 of 32 pens of 6–7 individuals after weaning, based on an equal distribution of BW measured 1 week before the start of the experiment. Littermates were distributed across treatment groups as much as possible to prevent that 1 litter received only 1 treatment. Pens were divided over 4 departments (8 pens per department) with an equal distribution of treatments within each department. Treatments were administered from approximately 40 (2.6 SD) days of age onwards weighing on average 9.5 (2.0 SD) kg of body weight. Treatments consisted of a 2×2 factorial design of dietary carbohydrate and arginine supplementation on a commercial basal diet (diets produced by Research Feed Plant, ForFarmers BV, Heijen, The Netherlands), which remained similar for all animals (see Tables 1 and 2 for the dietary component composition). The carbohydrate level consisted of a diet with 12.5% cornstarch and 12.5% dextrose added to the commercial basal diet (high carbohydrate diet; C+) versus a diet in which the cornstarch and dextrose was replaced with an isocaloric (based on MJ NE/kg) 8.9% soya bean oil (low carbohydrate diet; C−). This contrast of carbohydrate level was determined from previous experiments as the largest possible contrast conceivable in commercial diets in terms of food uptake and digestion (Wientjes et al., 2013). Arginine (L-arginine, Daesang Corp., Seoul, South Korea) supplementation consisted of 0.8% arginine added to the commercial basal diet (A+) versus 1.64% alanine (L-alanine, Omya Hamburg GmbH, Hamburg, Germany) supplemented to the basal diet as the isonitrogenous control (A−) as described by others (He et al., 2011; Shan et al., 2012; Zheng et al., 2013). All dietary components are described as fed. The 2×2 factorial treatment design resulted in the following treatment combinations termed treatment groups: C+A+, C+A−, C−A+, C−A−. The dietary treatments fed were isocaloric and were initially administered at approximately 95% of ad libitum energy uptake determined in a previous experiment using the same line of gilts (de Koning et al., 2013). During the current experiment, it was observed that the amount of feed presented to the high carbohydrate treatment group resulted in regular feed residuals (see Fig. 1), which could cause differences in energy uptake with the isocalorically fed low carbohydrate diets. Therefore, the amount of feed administered to all groups was lowered to approximately 85 to 90% of the estimated ad libitum intake. All gilts received feed in 2 portions per day (8:00 h and 16:00 h) in 2 troughs with ample feeding space and with metal bars separating individual feeding places. Feed residuals were collected and weighed after each day in the morning before the first feeding bout.

After weaning, all gilts received first the pelleted weaning diet (10.3 MJ NE/kg, 171 g/kg CP, 12.7 g/kg ileal digestible lysine). Subsequently, gilts changed to 3 successive diets in time each containing 1 of the 4 dietary treatments, adapted to their feed uptake and age (Tables 1 and 2). Diets were switched gradually over a 2 day period in which diets were offered as a 50% mixture of the old and new diets. Gilts were switched at 40 days of age to a pelleted grower diet (based on 1 kg of the C+ diet: 10.1 MJ NE/kg, 12.1 g/kg ileal digestible lysine; 6.3 g/kg calcium; 5.5 g/kg phosphorus); at 77 days of age to a pelleted rearing diet 1 (based on 1 kg of the C+ diet:9.7 MJ NE/kg, 10.0 g/kg ileal digestible lysine; 8.0 g/kg calcium; 5.5 g/kg phosphorus); at 116 days of age to a pelleted rearing diet 2 (based on 1 kg of the C+ diet: 9.5 MJ NE/kg, 6.5 g/kg ileal digestible lysine; 8.0 g/kg calcium; 5.5 g/kg phosphorus).

2.4. Blood sampling

All blood sampling was performed using EDTA as an anticoagulant. To determine if dietary treatments affected glucose and insulin profiles, blood samples were taken at the end of the experiment at 167 (2.5 SD) days of age of 10 randomly selected gilts per treatment group. Blood sampling occurred through cannulation of the ear vein. In 6 gilts cannulation was not successful as the veins were too small (number of gilts sampled: C+A+ n=8; C+A− n=10; C−A+ n=8; C−A− n=8). The insulin and glucose profiles could not be obtained at younger age, as the veins in the ear are still too small for the cannulation procedure. Cannulation of the ear vein was performed as described in Wientjes et al.