Livestock Science ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Contents lists available at ScienceDirect

Livestock Science

journal homepage: www.elsevier.com/locate/livsci

Intrauterine growth retardation increases lipid deposition in adipose tissue of pigs in response to high-fat/high energy diets

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ARTICLE INFO

Article history:
Received 30 October 2013
Received in revised form
20 March 2015
Accepted 21 March 2015

Keywords:
Adipose tissue
High-fat diets
Intrauterine growth retardation
Lipid metabolism
Pigs

ABSTRACT

The objective of this study was to investigate the effects of postweaning high-fat (HF)/high energy diets on lipid metabolism response in adipose tissue of normal birth weight (NBW) and intrauterine growth retarded (IUGR) pigs. Twenty NBW and twenty IUGR male piglets were fed either a control diet (without lard) or a HF diet (supplemented with 10% lard) from weaning (d 28) to slaughter at 111.4 ± 2.2 kg of body weight. Feed intake and body weight of pigs were recorded monthly. Blood and backfat samples were collected at the end of the experiment and analyzed for plasma levels of metabolites and hormone, activities and mRNA expressions of enzymes involved in lipid metabolism. The results showed that plasma concentrations of leptin and cholesterol, backfat thickness, index of backfat thickness, and mRNA expressions of leptin and adipocyte differentiation-related protein (ADRP) in backfat were affected by the interaction of birth weight and postweaning diet ($P < 0.05$). Compared with NBW littermates, IUGR pigs had lower average daily feed intake (ADFI) and average daily gain (ADG) but greater slaughter age and plasma levels of triglyceride ($P < 0.01$). Lipid content, adipocyte diameter, activities of fatty acid synthase (FAS) and malic enzyme (ME), mRNA expressions of FAS and peroxisome proliferator-activated receptor gamma (PPARγ) in adipose tissue of IUGR pigs were greater than that of NBW pigs ($P < 0.01$). Moreover, IUGR pigs had lower glucose-6-phosphate dehydrogenase (G-6-PDH) activity and mRNA levels of HSL compared with NBW pigs ($P < 0.01$). Pigs fed HF diets had lower ADFI, slaughter age ($P < 0.01$), mRNA expression abundances of LPL and FAS ($P < 0.01$), and activities of FAS and ME ($P < 0.05$) but greater ADG, plasma levels of triglyceride ($P < 0.05$), and gain to feed ratio than pigs fed control diets. In summary, our results indicated that IUGR pigs had greater capability in adipose tissue lipid deposition than that of NBW offspring in response to postweaning HF/high energy diets.

1. Introduction

Intrauterine growth retardation (IUGR), resulting in lower body weight at birth, confers persistent effects on growth performance and energy metabolism of the offspring (Wu et al., 2006). The retarded growth of fetus in utero, which is naturally occurring in pigs, is mainly caused by insufficient nutrient intake from mother via the placenta during the period of fetal development (Wu et al., 2006). It has been reported that IUGR affects postnatal growth potential and meat quality traits of pigs (Kühn et al., 2002; Quiniou et al., 2002; Bee, 2004; Poore

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http://dx.doi.org/10.1016/j.livsci.2015.03.018
1871-1413/

and Fowden, 2004; Gondret et al., 2006; Beaulieu et al., 2010; Nissen and Oksbjerg, 2011). Birth weight has a substantially greater impact on growth performance of pigs after weaning than increasing nutrient intake during lactation (Wolter et al., 2002). Generally, piglets with a birth weight less than 1.1 kg grow slower and less efficiently, and produce carcasses with a higher proportion of fat and less muscle than their heavier littermates at the same slaughter weight (Powell and Aberle, 1980; Wolter et al., 2002; Gondret et al., 2006).

While some of previous experiments reported that IUGR increases fat deposition in skeletal muscle and adipose tissue of pigs compared with normal birth weight (NBW) pigs (Gondret et al., 2006; Liu et al., 2012), some works showed no effect of birth weight on lipid deposition (Powell and Aberle, 1980; Wolter et al., 2002; Gondret et al., 2005). Previous studies showed that the effects of birth weight on lipid metabolism were contradictory among weaning pigs (Liang et al., 2011) and pigs with market weight (Gondret et al., 2006). Using a maternal malnutrition-model, Liang et al. (2011) found that IUGR piglets had a lower fat deposition and a higher lipolytic activity in adipose tissue than NBW piglets at weaning. However, Gondret et al. (2006) reported that IUGR pigs had a greater lipid store in backfat and subcutaneous fat at slaughter weight compared with NBW pigs.

The growth rate, carcass composition, and meat quality of pigs are influenced by daily feed intake and dietary nutritional concentration (Millet et al., 2006; Ruusunen et al., 2007; Hinson et al., 2009; Nissen and Oksbjerg, 2011). To date, little information was published to report the interactive effects of birth weight and postnatal nutrition on lipid metabolism of pigs. According to Nissen and Oksbjerg (2011), the growth performance and most traits of meat quality were influenced by birth weight and no effect of interaction between birth weight and dietary protein level was found. The objective of the current study was to compare effects of postweaning diets (control or HF) on growth performance, lipid store, gene expression abundances and enzymatic activities of lipid metabolism-related factors in backfat of NBW and IUGR pigs at the same slaughter weight. We tested 2 hypotheses: (1) that IUGR pigs had a greater potential in lipid deposition than NBW pigs, and (2) that postweaning HF/high energy diets increased lipid deposition in adipose tissue of IUGR pigs.

2. Materials and methods

The experimental protocols for this study were approved by the Animal Care Advisory Committee of Southwest University of Science and Technology, Mianyang, Sichuan Province.

2.1. Animals and experimental design

Piglets from twenty Landrace × Yorkshire sows (second parity) mated to Duroc boars were used in the current study. The sows were fed twice daily and feed intake was 2.2 kg per day during gestation. Digestible energy (DE) and crude protein (CP) levels in the diet of sows were 15 MJ/kg and 150 g/kg feed, respectively. Sows were fed ad libitum a diet containing 18 MJ/kg of DE and 175 g of CP/kg feed during lactation. Body weight of each piglet was recorded at birth. At weaning (d 28), one NBW male piglet (average birth weight) and one IUGR male piglet (2 standard deviations below the average birth weight of piglets) from each litter (two piglets per litter) were selected such that twenty male NBW piglets and twenty male IUGR piglets were used in the present study. Average body weight of NBW and IUGR piglets at weaning was 8.6 and 5.7 kg, respectively. The NBW and IUGR piglets were penned individually, and randomly fed ad libitum either to a control diet (C, without lard) or a high-fat diet (HF, supplemented with 100 g/kg lard) (Table 1) from weaning to slaughter at 111.4 ± 2.2 kg of body weight. Diets composition was changed according to the nutrient requirements for pigs at each growth period (NRC, 2012). Body weight and feed intake of pigs were recorded monthly. Average daily feed intake (ADFI), average daily gain (ADG), and gain to feed ratio for each treatment group were calculated from weaning to slaughter.

2.2. Sample collection and backfat thickness

At slaughter, blood samples were collected by venipuncture after the pigs were fasted 8 h and EDTA–plasma samples were stored at −20 °C. Pigs were slaughtered by electrical stunning and exsanguinated at 111.4 ± 2.2 kg of body weight. Mean backfat thickness was calculated by the average of values measured at the first rib, last rib, and last lumbar vertebra of the left half carcass, using a sliding caliper. The index of backfat was calculated according to the ratio of backfat thickness to body weight of pigs (Liang et al., 2011).

Adipose tissue samples containing the upper and middle layers were removed from backfat (first lumbar vertebra) immediately after slaughter. The pooled backfat slices from the two layers were collected in liquid nitrogen, and then stored at −80 °C until analyses of enzymes activities and mRNA expression abundance. A backfat sample was restrained on flat stick and used for the determination of adipocyte diameter.

2.3. Plasma metabolites and hormone

Plasma concentrations of glucose, triglyceride and cholesterol were determined using colorimetric methods with spectrophotometer (Thermo, Waltham, MA, USA) by respective commercial kits (Nanjing Jiancheng Institute of Bioengineering, Nanjing, Jiangsu, China). The protocols used in the assay were according to the manufacturer's instructions, and absorbance of glucose, triglyceride and cholesterol were measured in a spectrophotometer at 505, 546, and 546 nm, respectively (Jingbo et al., 2013). Leptin concentrations in plasma were determined with a commercial RIA kit purchased from Beijing North Institute of Biotechnology (Beijing, China). The intra- and inter-assay coefficients of variations were 5% and 10%, respectively. The detection limit was 0.45 ng/mL.

Please cite this article as: Liu, J.B., et al., Intrauterine growth retardation increases lipid deposition in adipose tissue of pigs in response to high-fat/high energy diets. Livestock Science (2015), http://dx.doi.org/10.1016/j.livsci.2015.03.018