



Maternal dietary fat affects the LT muscle fatty acid composition of progeny at weaning and finishing stages in pigs

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ARTICLE INFO

Article history:

Received 26 September 2013

Received in revised form 12 October 2013

Accepted 23 October 2013

Keywords:

Maternal dietary fat

Lactation

Colostrum

LT muscle

Fatty acid composition

ABSTRACT

The present study was conducted to investigate whether maternal dietary fat affects the fatty acid composition of the longissimus thoracis (LT) muscle in offspring pigs at weaning and finishing stages. Fourteen sows were randomly assigned to a control or a high fat (HF) group. The HF sows received a diet containing 8% corn oil starting seven days before farrowing until weaning. The results showed that a high-fat diet significantly increased the contents of serum-lipid-related indexes in the sows. Although the triglyceride content did not change, the C18:2n-6 content was higher in the colostrum and in the LT muscle of offspring pigs at both investigated stages. The total n-6 content and the n-6/n-3 ratio generally increased. This study demonstrated that maternal dietary fat during lactation affects the fatty acid composition of the LT muscle of progeny at weaning, and can have persistent effects in later life.

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1. Introduction

The dietary lipid contents and fatty acid composition have received much attention in recent years due to the increasing problems of obesity and metabolic diseases throughout the world. Fatty acids are used for energy and, in the case of essential fatty acids, as signal molecules that regulate animal growth, appetite and inflammation (Zhu, Ma, Long, Du, & Ford, 2010). In addition, the dietary ratios of omega-3 (n-3) to omega-6 (n-6) polyunsaturated fatty acids (PUFAs) have been implicated as controlling markers of metabolic syndrome, including insulin sensitivity and adiposity (Burghardt et al., 2010). Therefore, the fatty acid composition of meat is a subject of concern because meat constitutes the main lipid source for humans (Biesalski, 2005; Enser et al., 1998; Givens, 2007; Givens, Kliem, & Gibbs, 2006). Thus, knowing the factors affecting the fatty acid composition of the skeletal muscles of pigs is important.

Diet manipulation has been found to have a profound influence on body composition. Dietary fat can influence the skeletal muscle fatty acid composition (Andersson, Nälén, Tengblad, & Vessby, 2002; Ramsay, Evock-Clover, Steele, & Azain, 2001). However, in addition to this direct effect of dietary fat on the body fatty acid

composition, recent evidence from epidemiological, clinical and animal studies suggests that the maternal well-being during pregnancy and lactation may influence the offspring's lipid metabolism and lead to the development of obesity (Taylor & Poston, 2007), type 2 diabetes (Prentice, 2001) and dyslipidemia (Ghosh, Bitsanis, Ghebremeskel, Crawford, & Poston, 2001) later in life. During the lactation period, it is common for the sows to lose weight due to fat and protein mobilization (McNamara & Pettigrew, 2002). Therefore, fat is often added to the diet of lactating sows. However, it is still unclear whether the dietary fat consumed by the sow during the lactation period influences the fatty acid composition of the offspring pigs.

The early period in the lifecycle is critical for body lipid deposition (Wells, 2007). It has been shown that the maternal dietary fat during the perinatal period affects the type and quantity of the fatty acids in milk, which is one of the most important pathways to afford nutrition for neonates (Innis, 2011; Lauridsen & Danielsen, 2004). A further study has indicated that the administration of different oils to sows during lactation can alter the fatty acid composition of the offspring piglets at weaning, although the type of fatty acids was not consistent (Vicente, Isabel, Cordero, & Lopez-Bote, 2013). However, it is unknown whether the maternal dietary fat during lactation has a long-lasting effect on the offspring's fatty acid composition. Therefore, in the present study, we added corn oil to the diet of lactating sows and analyzed the influence of dietary fat on the serum lipid profile and colostrum fatty acid composition of the sows and the longissimus thoracis (LT) muscle fatty acid composition of the offspring pigs at the weaning and finishing stages. The study was conducted to clarify whether maternal dietary fat has a long-lasting effect on the offspring's skeletal muscle fatty acid

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composition in pigs and may provide new insights with probable importance for human fatty-acid-related disease prevention.

2. Materials and methods

2.1. Ethics statement

The experiment was conducted following the guidelines of the Animal Ethics Committee at Nanjing Agricultural University in China. The slaughter and sampling procedures complied with the “Guidelines on Ethical Treatment of Experimental Animals” (2006) No. 398 set by the Ministry of Science and Technology of China and “the Regulation Regarding the Management and Treatment of Experimental Animals” (2008) No. 45 set by the Jiangsu Provincial People’s Government.

2.2. Animals and experimental design

Fourteen Large White $\times$ Landrace sows (2rd to 3rd parity) were randomly assigned to either a control ($n = 6$) or a high-fat diet (HF, $n = 8$) group. Starting seven days before farrowing and continuing throughout the lactation period, the control sows were fed a control diet, and the sows in the HF group were fed a diet containing 8% corn oil (Table 1). All of the sows used in this study were artificially fertilized with a mixture of semen samples obtained from four boars. The sows were housed individually in pens ($2.1 \text{ m} \times 2.2 \text{ m}$), fed a supply of 4.0 kg/d twice daily and provided with ad libitum access to water. Little size was adjusted to 7 to 9 pigs per litter at 24 h post parturition in the same group. The newborn piglets were marked with ear tags and allowed free access to their mothers and weaned at 28 days of age. Then the weaned piglets moved from the farrowing barn into the nursery and when the pigs grew to around 25–30 kg, they were moved to the finishing barn. After weaning, all the piglets (including the piglets from the control and HF group) were randomly divided into 5 pens ($5.0 \text{ m} \times 5.2 \text{ m}$) fed with the standard regimen diet comprising of weaning, growing and finishing diets (Table 1). All the piglets were maintained under identical feeding conditions, and routine farm

management procedures were followed. At weaning (28 days) and finishing stages (six months of age), all the offspring pigs were weighed (Table 3) and one male pig with the mean body weight ($\pm 10\%$) was selected from each litter and slaughtered. The average body weights of selected pigs in the control group and HF group were $5.88 \pm 0.93 \text{ kg}$ and $5.28 \pm 0.86 \text{ kg}$ at the weaning stage, respectively. The average body weights of selected pigs in the control group and HF group were $80.06 \pm 4.72 \text{ kg}$ and $78.12 \pm 4.59 \text{ kg}$ at the finishing stage, respectively.

2.3. Measurements and sampling

The colostrum samples were collected from the mammary glands of each sow after parturition and immediately frozen at -20°C for chemical analysis. The body weight was recorded at the weaning and finishing stages. The blood and longissimus thoracis (LT) muscles (without visible fat and connective tissues) were obtained from the left half of the carcass at weaning and finishing stages, snap-frozen in liquid nitrogen and stored at -80°C until further analysis.

2.4. Serum and LT muscle triglyceride content, meat quality and colostrum index

The serum and LT muscle triglycerides were determined with enzymatic colorimetric methods using commercial kits (Nanjing Jian Cheng Bioengineering Institute, China; Beijing Applygene Technology Co., Ltd., China, respectively). The pH was measured in the LT muscle at the last rib on the left side 24 h postmortem. Meat color and drip loss for the muscle at the last rib on the right side were determined. The color and pH were measured using a Minolta chroma meter CR-400 (Japan) and Testo 205 pH meter (Germany), respectively. The drip loss was measured over 24 h using approximately 100 g of LT muscle through the plastic bag method described by Honikel (1998).

The colostrum total protein was measured using a Pierce BCA Protein Assay kit (no. 23225, Thermo). The colostrum total fat was determined according to the creatinocrit method (Lucas, Gibbs, Lyster, & B, 1978).

2.5. Fatty acid analysis

The colostrum lipids were extracted and transesterified according to the method developed by Christopherson and Glass (1969) and analyzed by GC using a Shimadzu GC-2010 Plus instrument (Japan). The analysis conditions were as follows: capillary column, $100 \text{ m} \times 0.25 \text{ mm}$ inner diameter; film thickness, $0.25 \mu\text{m}$. The temperature program was as follows: initial temperature 140°C (5 min hold), $40\text{--}240^\circ\text{C}$ ($6^\circ\text{C}/\text{min}$) and 15 min hold. The injector temperature was 260°C , and the detector temperature was 280°C . The carrier gas was nitrogen with a flow rate of $1.0 \text{ mL}/\text{min}$ and a split ratio of 30:1. The fatty acid concentrations were calculated based on their peak areas relative to the internal standard. The individual fatty acids were identified by comparing the retention time of the peak with that of standard fatty acid methyl esters (37-component FAME Mix, Sigma). The fatty acids were quantified as the percentage of total fatty acids in the sample.

The LT muscle lipids were extracted with a mixture of chloroform/methanol (2:1 v/v), as described by Folch, Lees, and Sloane Stanley (1957). The intramuscular fatty acid content was quantified through a one-step procedure as described by Sukhija and Palmquist (1988) from lyophilized samples. The fatty acid methyl esters were analyzed by GC using a Shimadzu GC-2010 Plus instrument. The analysis conditions were as follows: capillary column, $30 \text{ m} \times 0.25 \text{ mm}$ inner diameter; film thickness, $0.25 \mu\text{m}$. The temperature program was as follows: the initial temperature 100°C (5 min hold), $100\text{--}220^\circ\text{C}$ ($10^\circ\text{C}/\text{min}$). The GC parameters were as follows: injector temperature 200°C , detector temperature 220°C , flame ionization detector, hydrogen carrier gas, flow rate $1.0 \text{ mL}/\text{min}$, and split ratio 33:1.

Table 1
Composition and nutrient content of the experimental diet.

Ingredient, (%)	Sows lactation period		Weaning	Offspring growing	Finishing
	Control	HF	5 weeks of age to 20 kg	20–60 kg	60–100 kg
Corn	65.83	55.86	64	65.5	66
Soybean meal	20.17	22.14	23	24	22
Bran	8	8	5	6.5	8
Fish meal	2	2	2	0	0
Soya bean oil	0	0	2	0	0
Premix ^a	4	4	4	4	4
Corn oil	0	8	0	0	0
Nutrition standards, (%)					
Crude protein	17.46	17.46	18.13	17.71	17.09
Ether extract	3.3	10.98	5.17	3.21	3.25
Crude fiber	2.78	2.72	2.70	2.87	2.87
Ca	0.19	0.19	0.20	0.12	0.12
P	0.46	0.44	0.44	0.40	0.41
Digestible energy, (Mcal/kg)	3.29	3.71	3.44	3.32	3.30

^a The premix contains the following (per kilogram): vitamin A, 125–175 KIU; vitamin D3, 35–125 KIU; vitamin E, $\geq 1000 \text{ mg}$; vitamin K3, $\geq 50 \text{ mg}$; vitamin B1, $\geq 20 \text{ mg}$; vitamin B2, $\geq 120 \text{ mg}$; vitamin B6, $\geq 28 \text{ mg}$; vitamin B12, $\geq 0.5 \text{ mg}$; niacin, $\geq 700 \text{ mg}$; pantothenic acid, $\geq 400 \text{ mg}$; folic acid, $\geq 20 \text{ mg}$; biotin, $\geq 6 \text{ mg}$; choline, 12,500 mg; iron sulphate, 1750–18,000 mg; copper sulphate, 300–875 mg; zinc oxide, 2000–3750 mg; manganese sulphate, 1250–3500 mg; iodized sulphate, 10–250 mg; cobalt sulphate, 25–50 mg; selenium sulphate, 5–12.5 mg; lysine, $\geq 1.0 \text{ mg}$; calcium, 11–22 mg; and total phosphorus, $\geq 2.5 \text{ mg}$; sodium chloride, 5.4–15%.

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