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Early dietary amino acid restrictions and flaxseed oil supplementation on the leanness of pigs and quality of pork: Growth performance, serum metabolites, carcass characteristics, and physical and sensory characteristics of pork

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ABSTRACT

A total of 64 pigs (Yorkshire) were used to investigate the effect of early dietary amino acid (AA) restrictions [100 or 80% of the 2012 NRC standardized ileal digestible (SID) Lys requirements during the grower and finisher-1 phases] and flaxseed oil supplementation [0 or 3% (+2% poultry fat)] in a 2 × 2 factorial arrangement of treatments on grower-finisher pigs. At 24.7 ± 0.5 kg body weight (BW), pigs were randomly assigned to 4 grower diets with 4 gilt and 4 castrated male pens/treatment and 2 gilts or 2 castrated males/pen, and switched to fnisher-1 diets when they reached 51.2 ± 0.3 kg. Pigs were offered common finisher-2 diets after 80.0 ± 0.4 kg, and those received 0 or 5% lipids during the grower and finisher-1 phases were continued to receive 0 or 5% lipids. Ultrasound backfat measurements and blood samples were collected at the end of the grower, finisher-1, and finisher-2 phases, and pigs were harvested at 110.5 ± 0.5 kg to assess carcass traits and physical and sensory characteristics of pork. During the grower phase, although pigs consumed less feed, SID Lys, and digestible energy (DE; $P < 0.015$), their average daily BW gain was not really depressed by the dietary AA restrictions. During the finisher-1 phase, however, pigs fed the AA restricted diets had greater BW gain ($P = 0.042$) and utilized SID Lys more efficiently ($P < 0.001$) for BW gain than those fed the unrestricted diets. Pigs fed the diets supplemented with lipids had lower feed intake ($P = 0.007$) but greater BW gain ($P = 0.03$) during the grower phase, and their BW gain:feed ($P < 0.045$) was improved during the all phases of production. Overall BW gain was not affected by the early dietary AA restrictions, but overall efficiency of feed, SID Lys, or DE utilization for BW gain ($P < 0.005$) was improved by the AA restrictions. Similarly, the early dietary AA restrictions had no effect on fat-free lean (FFL) gain but increased FFL gain:SID Lys ($P < 0.001$) and tended to increase FFL gain:DE ($P = 0.095$). Serum urea-N ($P < 0.026$) at the end of the grower and finisher-1 phases was reduced, and serum glucose ($P = 0.027$) at the end of the grower phase was increased by the dietary AA restrictions. The dietary lipids tended to increase and increased serum triglycerides at the end of the grower ($P = 0.075$) and finisher-1 and 2 ($P < 0.018$) phases, respectively, and reduced urea-N ($P = 0.037$) at the end of the finisher-2 phase. At the end of the finisher-1 phase, the dietary lipids increased serum cholesterol in pigs fed the unrestricted diet but had no effect on those fed the AA restricted diet (AA restrictions x lipid supplementation, $P = 0.029$). The dietary AA restrictions tended to reduce the initial tenderness ($P < 0.057$) and reduced flavor intensity ($P = 0.048$) of pork slightly. Belly firmness ($P < 0.001$) was reduced and off-flavor ($P = 0.007$) was increased slightly by the dietary lipids. There was no effect of dietary treatments on ultrasound backfat. In conclusion, the dietary lipids improved BW gain:feed but reduced belly firmness and increased off-flavor slightly. The dietary AA restrictions had no effect on overall BW gain or FFL gain but improved overall efficiency of AA and DE utilization for BW gain and FFL gain.

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1. Introduction

Satisfying the consumer by providing high-quality pork is an integral part of successful and sustainable pig production. Unfortunately, the effort to satisfy consumer demands by producing leaner pigs over the years has resulted in the reduction of intramuscular fat (IMF) content, which has adverse effects on organoleptic characteristics of pork (Cisneros et al., 1996; Gerbens et al., 2001). Because of a poor relationship between IMF and subcutaneous fat thickness, however, the IMF content can be increased while maintaining the leanness of pigs (Dannenberger et al., 2012; Jones et al., 1992). Furthermore, IMF may have positive attributes on humans such as beneficial effects on low density lipoprotein-cholesterol and coronary heart disease (Baghurst, 2004; Calder and Yaqoob, 2009), and such beneficial effects can be enhanced further if the increased IMF content can be achieved by omega-3 fatty acids (ω−3 FA; Corino et al., 2014; Dugan et al., 2015; Huang et al., 2008).

The results of previous studies indicated that pigs subjected to early dietary amino acid (AA) restrictions can exhibit compensatory growth (Chiba, 1994; Chiba et al., 2002; Fabian et al., 2002), utilize nutrients more efficiently (Chiba et al., 2002; Fabian et al., 2002), and reduce N excretion (Fabian et al., 2004). Compensatory growth, therefore, can have a positive impact on the overall efficiency of pig production and environment. Furthermore, by taking advantage of compensatory growth, carcass fat can be reduced (Chiba, 1995; Chiba et al., 1999) to satisfy the consumer demand for leaner pork, and the IMF content may be increased (da Costa et al., 2004; Dannenberger et al., 2012) to enhance organoleptic characteristics of pork simultaneously.

Over the years, several investigators have reported that de novo lipogenesis in pigs can be reduced by dietary lipids (Allee et al., 1971a, 1971b; Lin et al., 2013). It seems that body fat can be reduced by including up to 5% lipids in the pig diet, but more than 5% dietary lipids is likely to reduce the leanness of grower-finisher pigs (Moser, 1977). It is possible that dietary supplementation of flaxseed oil, which is high in ω−3 FA, can not only increase the ω−3 FA content but also enhance leanness of pork.

A study was conducted to investigate the effect of early dietary AA restrictions during the grower and finisher-1 phases and supplementation of flaxseed oil on: a) compensatory growth, b) serum metabolite profile, c) carcass characteristics, d) physical and sensory characteristics of pork, e) IMF content, f) FA composition, and g) expression of selected genes associated with lipid metabolism. In this article, the results of growth performance, serum metabolites, carcass characteristics, and physical and sensory characteristics of pork are reported, and other response criteria will be reported elsewhere.

2. Materials and methods

2.1. Grower-finisher pigs and facility

The protocol for animal care was approved by the institutional Animal Care and Use Committee of Auburn University (Auburn, AL, US). A total of 64 pigs (Yorkshire) weighing approximately 20 kg were selected and moved into an open-sided grower-finisher unit. Pigs were assigned to 32 pens (> 1.35 m^2/pig) based on their weight, sex, and ancestry with 2 gilts or 2 castrated males per pen. Pens were assigned randomly to 4 dietary treatments in a 2 × 2 factorial arrangement of treatments with 4 gilt and 4 castrated male pens per treatment. Because of the availability of pigs at that time, the study was conducted in 2 trials. Each trial used 16 gilts and 16 castrated males, and 2 trials were approximately 4 wk apart. The average minimum and maximum daily temperatures in the grower-finisher unit during the study were 7.9 and 19.3°C, respectively.

When the average pen weight reached 24.7 ± 0.5 kg body weight (BW), pigs were offered the grower diets. Pigs were switched to finisher-1 and finisher-2 diets when they reached 51.2 ± 0.3 and 80 ± 0.4 kg, respectively. Pigs fed 0 or 5% lipids during the grower and finisher-1 phases were continued to receive 0 or 5% dietary lipids during the finisher-2 phase. Pigs were allowed ad libitum access to feed and water throughout the study. Pig weights and feed consumption data were collected weekly. Pigs were harvested after overnight fast when they reached the target BW of 110.5 ± 0.5 kg. On the average, pigs were approximately 8, 14, 18 and 22 wk of age for the beginning of the grower, finisher-1, and finisher-2 phases, and at the end of the study, respectively.

2.2. Dietary treatments

A fundamental assumption of the dietary treatment was that Lys is the first-limiting AA in all diets. Diets were supplemented with 5% lipids to take advantage of inhibitory effect of dietary lipids on lipogenesis (Allee et al., 1971a, 1971b; Moser, 1977). However, to avoid potential adverse effects of excess flaxseed oil supplementation on pork characteristics, diets were supplemented with 3% flaxseed oil (Bryhni et al., 2002; Romans et al., 1995; Wood et al., 2003), and the remaining 2% lipids were provided by poultry fat. The analyzed composition of corn and soybean meal (Ajinomoto Heartland, Chicago, IL, US) and FA composition of poultry fat and flaxseed oil (AOAC, 1995) are presented in Tables 1 and 2, respectively. Flaxseed oil was obtained from a commercial source (TA Foods Ltd., Yorkton, SK, Canada).

For each of the grower and finisher-1 phases, 2 corn-soybean meal diets were formulated to contain 100 or 80% of the standardized ileal digestible (SID) Lys recommendation (NRC, 2012), and each diet was supplemented with 0 or 5% lipids (3% flaxseed oil + 2% poultry fat; Tables 3 and 4). For the finisher-2 phase, a common, corn-soybean meal diet was formulated to satisfy the SID Lys recommendation (NRC, 2012), and it was supplemented with 0 or 5% lipids (3% flaxseed oil + 2% poultry fat; Table 4). The effort was not made to maintain a constant AA balance, but a proportion of each indispensable AA relative to Lys was above the balanced protein (NRC, 2012). Dietary Lys (as well as other AA), Ca, and P contents were adjusted accordingly to the changes in the digestible energy (DE) content to maintain constant Lys, Ca, and P to DE ratios (Chiba et al., 1991a, 1991b). Feed samples were collected from every batch of diets prepared and pooled, and subsamples were analyzed for crude protein (Method 991.20; AOAC, 1995).

2.3. Ultrasound measurements and blood samples

For gross assessment of alterations in body composition during the restriction and realimentation phases, backfat thickness of each pig was

Table 1
Composition of corn and soybean meal without hulls (g/kg; as-fed)[a,b].

Item	Corn	Soybean meal
Dry matter	861.4	876.6
Crude protein	82.0	480.6
Arg	4.1	32.7
His	2.5	11.7
Ile	3.0	20.9
Leu	10.4	34.2
Lys	2.7	28.2
Met	1.9	06.2
Cys	2.0	06.5
Met + Cys	3.9	12.7
Phe	3.9	23.3
Thr	3.1	18.0
Trp	0.7	6.2
Val	0.5	21.7

[a] Samples were analyzed by a commercial lab (Ajinomoto Heartland, Chicago, IL, US).
[b] Reported the values of 1 batch of sample.