Animal Feed Science and Technology 216 (2016) 251–261

Contents lists available at ScienceDirect

Animal Feed Science and Technology

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

Dietary peroxidized maize oil affects the growth performance and antioxidant status of nursery pigs

Andrea R. Hanson[a,1], Pedro E. Urriola[a], Lei Wang[b], Lee J. Johnston[c], Chi Chen[b], Gerald C. Shurson[a,*]

[a] Department of Animal Science, 385 AnSci/VetMed Bldg., 1988 Fitch Avenue, University of Minnesota, St. Paul, MN 55108, USA
[b] Department of Food Science and Nutrition, 330 ABLMS, 1354 Eckles Ave., St. Paul, MN 55108, USA
[c] West Central Research and Outreach Center, 46352 State Hwy 329, Morris, MN 56267, USA

ARTICLE INFO

Article history:
Received 11 January 2016
Received in revised form 23 March 2016
Accepted 24 March 2016

Keywords:
Caloric efficiency
Growth performance
Maize oil
Metabolic oxidation
Weaned pigs
Peroxidation

ABSTRACT

This experiment was conducted to evaluate the effects of increasing dietary levels of peroxidized maize oil on growth performance and antioxidant status of nursery pigs. Weanling barrows (n = 128; initial body weight (BW) = 6.3 ± 1.4 kg) were blocked by initial BW and assigned randomly to 1 of 32 pens. Within block, pens were assigned randomly to 1 of 4 dietary treatments: 90 g/kg unheated maize oil, 60 g/kg unheated maize oil +30 g/kg rapidly peroxidized (RO) maize oil, 30 g/kg unheated maize oil +60 g/kg RO maize oil, or 90 g/kg RO maize oil. Diets were formulated to contain identical levels of total maize oil and standardized ileal digestible Lys to metabolizable energy (ME) ratios. Maize oil was heated for 12 h at 185 °C (air flow rate = 12 L/min) to yield RO (PV = 5.7 meq O_2/kg; thiobarbituric acid reactive substances = 26.7 mg malondialdehyde eq/kg) maize oil. A 3-phase feeding program (phase 1 = d 0–4, phase 2 = d 4–14, and phase 3 = d 14–35) was used, and average daily gain (ADG), average daily feed intake (ADFI), gain to feed ratio (G:F), and energetic efficiency (g ADG/MJ of ME intake) were determined. Serum was collected on d 0, 14, and 35 from 1 pig per pen that was subsequently harvested to obtain liver and heart tissue. Final BW (19.5 vs 18.5 ± 0.6 kg for 0 vs 90 g/kg RO maize oil; $P < 0.15$) and ADG (377.5 vs 347.0 ± 13.6 g for 0 vs 90 g/kg RO maize oil; $P \leq 0.10$) tended to decline linearly with increasing dietary RO, but ADFI was not affected. Consequently, G:F ($P < 0.05$) declined linearly by 1.4–4% with increasing dietary concentrations of RO maize oil. The α-tocopherol content of serum declined with increasing dietary concentrations of RO maize oil (linear and cubic; $P < 0.01$). These data suggest that RO maize oil negatively affects growth performance and the efficiency of energy utilization of nursery pigs linearly and reduces serum α-tocopherol content.

Abbreviations: ADFI, average daily feed intake; ADG, average daily gain; ATTD, apparent total tract digestibility; BW, body weight; DMO, distillers maize oil; DDGS, dried distillers grains with solubles; G:F, gain to feed ratio; HPLC, high performance liquid chromatography; MDA, malondialdehyde; ME, metabolizable energy; MHD, Mulberry Heart Disease; PUFA, polyunsaturated fatty acids; PV, peroxide value; SID, standardized ileal digestible; TBARS, thiobarbituric acid reactive substances.

* Corresponding author.
E-mail address: shurs001@umn.edu (G.C. Shurson).
[1] Present address: SVC Research, P.O. BOX 269 St. Peter, MN 56082, USA.

http://dx.doi.org/10.1016/j.anifeedsci.2016.03.027
0377-8401/

1. Introduction

Lipids in maize and maize dried distillers grains with solubles (DDGS) provide a substantial portion of energy in United States swine diets. Distiller's maize oil (DMO) is extracted prior to manufacturing DDGS at more than 85% of ethanol plants in the United States and it is used for the production of biodiesel and animal feeds (Renewable Fuels Association, 2015). However, maize oil contains 540 g/kg polyunsaturated fatty acids (PUFA) that are susceptible to peroxidation (NRC, 2012). Peroxidation is accelerated by exposure to heat, air, moisture, and pro-oxidant metals, which may be introduced during feed ingredient processing and storage. Animal fats, vegetable oils, and other lipid-rich feed ingredients may be peroxidized to varying amounts depending on the temperature and duration of thermal exposure (Dibner et al., 2011; Song and Shurson, 2013).

Peroxidation degrades fatty acids into numerous secondary and tertiary peroxidation compounds (Spiteller et al., 2001; Seppanen and Csallany, 2002; Belitz et al., 2009), and degrades indigenous vitamin E (Seppanen and Csallany, 2002; Liu et al., 2014c). Feeding peroxidized lipids reduces gain efficiency (McGill et al., 2011a, b; Tavárez et al., 2011), growth rate (Boler et al., 2012; Liu et al., 2014b), and antioxidant status (Boler et al., 2012; Liu et al., 2014b) of swine and broilers. At the cellular level, peroxidized lipids attack lipid membranes, impair cell function and integrity, and contribute to apoptosis (Gutteridge, 1995).

Maximal dietary thresholds for inclusion of peroxidized lipids have not been established, and little information exists on the effects of increasing dietary concentrations of peroxidized lipids on growth performance of pigs. Therefore, the objective of this experiment was to investigate the effect of increasing dietary levels of peroxidized maize oil in iso-caloric diets on the growth and antioxidant status of nursery pigs. Maize oil was selected as the lipid source because of its high concentration of PUFA (NRC, 2012), and the increasing use of DMO in swine diets.

2. Materials and methods

2.1. Pig care, management, and dietary treatments

Experimental design and procedures were reviewed and approved by the Institutional Animal Care and Use Committee at the University of Minnesota. This experiment was conducted at the University of Minnesota Southern Research and Outreach Center Swine Research Facility in Waseca, Minnesota, with 128 barrows weaned at 19 days of age (BW = 6.3 ± 1.4 kg) from Topigs females (Winnipeg, Manitoba; Landrace x Yorkshire) sired by Duroc boars (Compart's Boar Store, Nicollet, MN). Sows were handled and fed according to the standard operating procedures of the research facility and fed common diets. Pigs were housed in pens (1.2 × 1.2 m; 4 pigs/pen), and each pen contained a dry feeder (3 feeder spaces) and a nipple drinker. Pigs were provided ad libitum access to water and experimental diets for 5 weeks.

Pigs were stratified by BW into 8 blocks, assigned to one of 4 pens within block, and pens were assigned randomly to 1 of 4 dietary treatments within each block. Dietary treatments were fed in 3 phases (phase 1 = days 0–4, phase 2 = days 4–14, and phase 3 = days 14–35) and included: 90 g/kg unheated maize oil, 60 g/kg unheated maize oil +30 g/kg rapidly peroxidized (RO) maize oil, 30 g/kg unheated maize oil +60 g/kg RO maize oil, and 9 g/kg RO maize oil. Within each phase, diets were formulated to contain similar metabolizable energy (ME) and nutrient content except for the ratio of RO to unperoxidized maize oil. Consequently, all treatments contained the same ratio of standardized ileal digestible (SID) Lys to ME within phase. All diets were formulated to meet or exceed NRC (2012) requirements for nursery pigs fed diets containing 15.9 Mcal ME/kg for SID Lys, Met + Cys, Thr, Trp, total Ca, and apparent total tract digestible (ATTD) P. Diets were formulated to contain 16.9, 16.3, and 14.9 g/kg SID Lys; 4.4, 4.1, and 3.5 g/kg ATTD P; and provide Ca:ATTD P ratios of 2.2:1, 2.3:1, and 2.5:1 for phases 1–3, respectively. All diets were provided in meal form and contained Mecadox® 2.5 (carbadox 5.51 g/kg; Phibro Animal Health, Teaneck, NJ), which provided 27.5 mg/kg carbadox to the diets. Carbadox is commonly added to nursery pig diets to control enteric pathogens in the United States.

Refined, deodorized, and bleached maize oil (Stratas Foods, Memphis, TN) was heated at 185 °C for 12 h with a constant forced air flow rate of 12 L/min to yield RO maize oil. After heating, maize oil was stored in barrels in the feed mill for 2 days before making phase 1 diets. Mean daily outdoor temperature at the research facility during the experiment was 23.3 ± 4.1 °C. Oil peroxide value (PV) was 1.7 and 5.7 meq/kg and thiobarbituric acid reactive substances (TBARS) content was 27.7 and 46.3 mg malondialdehyde (MDA) equiv./kg for unheated and RO maize oil, respectively.

2.2. Data and sample collection

Pigs were weighed individually on days 0, 4, 14, and 35, and pen feed disappearance was recorded at the end of each dietary phase. These data were used to calculate average daily gain (ADG), average daily feed intake (ADFI), gain to feed ratio (G:F), and energetic efficiency (g ADG/MJ of ME intake) of each pen.

In each pen, the pig closest to mean pen BW at day 0 was selected as the focal pig, and 20–30 mL blood (fed state) were collected via jugular venipuncture into vacutainer tubes coated with silicone (Becton Dickson, Franklin Lakes, NJ) on days 0, 14, and 35. Blood samples were allowed to clot at room temperature (5–10 min), stored at 4 °C (≤6 h), and centrifuged (1400*g* for 10 min). Serum was transferred into microcentrifuge tubes and frozen at −80 °C until further analysis. On day 35, focal pigs (n = 32) were euthanized by intravenous injection with sodium pentobarbital (>100 mg/kg BW). Intact livers and hearts