Livestock Science 195 (2017) 13–20

Contents lists available at ScienceDirect

Livestock Science

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

The effect of coated sodium butyrate supplementation in sow and nursery diets on lactation performance and nursery pig growth performance

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ARTICLE INFO

Keywords:
Coated sodium butyrate
Sow
Reproductive performance
Nursery pig
Growth

ABSTRACT

Three experiments were conducted to evaluate the effect of coated sodium butyrate (CSB) supplementation to peripartal and lactating sows and nursery pigs on lactation performance and nursery growth performance. In Exp. 1, a total of 43 gestating sows (d 81–92 of gestation) were allotted to 0 (n=15), 500 (n=16), or 1000 (n=12) ppm of CSB supplementation based on breed, parity and body weight (BW), and then fed treatment diets until weaning. In Exp. 2 and 3, a total of 144 weanling pigs (72 pigs for Exp. 2 and 3, respectively) from 0 or 1000 ppm CSB sow treatments in Exp. 1 were allotted within the sow treatment to 0, 500, or 1000 ppm of CSB supplementation in nursery diets based on breed and BW in a split plot design for a 35-d growth study. All pigs in Exp. 2 were injected with ovalbumin at weaning and d 14 postweaning as an immune challenge. In Exp. 1, there were no differences in sow BW, litter size, litter weight, lactation feed intake or milk composition among treatments. However, colostral IgG (P=0.06) and IgA (P=0.09) concentrations tended to increase quadratically as CSB supplementation levels increased. In Exp. 2, pigs from the 1000 ppm CSB sow treatment had greater BW at d 35 ($P < 0.01$), average daily gain (ADG; $P < 0.01$), average daily feed intake (ADFI; $P < 0.01$) and feed to gain ratio (F:G, P=0.07) than those from the 0 ppm CSB sow treatment. For the nursery treatments, ADG ($P < 0.05$) and ADFI (P=0.06) during the 35-d period increased linearly as CSB supplementation levels increased whereas F:G had a negative quadratic response (P=0.10). In Exp. 3, F:G for d 0–14 postweaning tended to be lower (P=0.09) in pigs from the 1000 ppm CSB sow treatment compared with those from the 0 ppm CSB sow treatment whereas BW, ADG, and ADFI ($P < 0.05$) during the 35-d period decreased linearly as CSB supplementation levels increased in the diets. In conclusion, CSB supplementation tended to increase colostral IgG and IgA concentrations in sows and improved growth performance of nursery pigs under an immune challenge when supplemented in the nursery diet.

1. Introduction

Butyrate is a short chain fatty acid produced by microbial fermentation in the large intestine of the animal (Bergman, 1990). In swine diets it has been used for nursery pigs to reduce diarrhea and overcome weaning stress (Fang et al., 2014; Piva et al., 2002). Previous studies demonstrated that sodium butyrate (SB) supplementation in the nursery diet improved growth rate, feed efficiency (Le Gall et al., 2009), and porcine intestinal development by increasing villi height, villi height to crypt depth, and mucosa thickness (Lu et al., 2008; Mazzoni et al., 2008). Additionally, it has been reported that SB supplementation enhanced immune function of piglets (Fang et al., 2014) and reduced pro-inflammatory cytokine production such as TNF-α and IL-6 (Wen et al., 2012), and butyric acid had a potential to protect the body from bacterial infection such as *E.coli, Enterococcus,* and *Salmonella* (Boyen et al., 2008; Sun et al., 1998). However, most studies supplementing SB in swine diet have focused on nursery pigs where SB was used as an alternative to an antibiotic growth promoter. Thus, the effect of SB supplementation in sow diets has not been as well documented. Because butyrate is an energy source for pigs (Bergman, 1990) and has functions on the immune system and gut integrity including antibacterial and anti-inflammatory properties, SB supplementation in sow diets may influence reproductive performance, and pre- and postweaning growth performance of their progeny. Kotunia et al. (2004) reported that piglets fed by artificial milk formulas containing 0.3% SB on a dry matter basis had increased crypt depth, villi height, and mucosa thickness in jejunum and ileum which was associated with increased growth rate. In a recent study, Lu et al. (2012) reported that piglets from the sows that were supplemented with 0.3% butyrate from late gestation to lactation had

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http://dx.doi.org/10.1016/j.livsci.2016.11.005
Received 9 June 2016; Received in revised form 7 September 2016; Accepted 3 November 2016
1871-1413/

increased growth rate at 12 wk of age. In contrast, Wang et al. (2014) reported no effect of SB supplementation in the lactation diet on litter size, litter growth and lactation feed intake. However, in those studies, response measures were limited to only reproductive performance of sows and growth performance of nursery pigs whereas they lacked information about immunological parameters, milk composition and blood clinical chemistry. Furthermore, it has not been confirmed whether or not there is a carryover effect or interaction when SB is supplemented in both sow and nursery diets. Therefore, the objective of this study was to evaluate effects of SB supplementation in sow and nursery diets on lactation performance, milk composition, colostrum immunoglobulin (Ig) concentrations and nursery growth performance without or with an immune challenge.

2. Materials and methods

The experiment was conducted under protocols approved by the University of Kentucky Institutional Animal Care and Use Committee and followed guidelines stated in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (Federation of Animal Science Societies, 2010).

2.1. Animals, dietary treatments, and housing conditions

2.1.1. Experiment 1

A total of 43 gestating sows (mean parity=3.6; Yorkshire, Yorkshire×Landrace; Group 1, n=26; Group 2, n=17) artificially inseminated with Duroc semen were allotted to 3 treatments at d 81–92 of gestation in a completely randomized design balanced for breed, parity, and body weight (BW). Dietary treatments were: 1) basal diet with 0 ppm of coated sodium butyrate (CSB) supplementation (control), 2) basal diet+500 ppm of CSB supplementation, and 3) basal diet+1000 ppm of CSB supplementation. A commercial product (CM3000, 30% microencapsulated SB; Hangzhou King Techina Feed Co., Ltd., China) was used for the experiment. During gestation, pregnant sows were housed individually in gestation stalls (0.57×2.13 m^2) and all sows were moved to farrowing crates (1.52×2.13 m^2) in an environmentally-controlled farrowing room at d 110 of gestation. The crates had a plastic coated woven wire floor area with heat lamps for piglets and were equipped with a drinking nipple and feed trough for sows. Sows were fed 1.9 kg/d of a common gestation diet before being assigned to dietary treatments. Once allotted to treatments, the sows were fed 1.9 kg/d of the experimental diets for gestation until farrowing. Farrowing sows were provided 3.2 kg of the experimental diets for the first 3 days until all feed was consumed in a day. The daily feed allowance was then increased by 0.9 kg every 3rd day until daily feed intake reached at least 6.4 kg, and then sows were provided on an ad libitum basis during lactation.

2.1.2. Experiments 2 and 3

In Exp. 2, 72 weanling pigs (Yorkshire×Landrace×Duroc, Yorkshire×Duroc) were selected at weaning from 0 (n=5 sows) and 1000 (n=4 sows) ppm CSB treatments in Exp. 1 to evaluate growth performance under an immune challenge and allotted within the sow treatment to 3 nursery treatments for 3 replicates with 4 pigs per pen (2 barrows and 2 gilts) based on breed and BW as a split plot design for a 35-d growth study. In Exp. 3, 72 weanling pigs (Yorkshire×Landrace×Duroc, Yorkshire×Duroc) were selected at weaning from 0 (n=5 sows) and 1000 (n=5 sows) ppm CSB treatments in Exp. 1 to evaluate growth performance with no immune challenge and allotted within sow treatment to 3 nursery treatments for 3 replicates with 4 pigs per pen (2 barrows and 2 gilts) based on breed and BW as a split plot design for a 35-d growth study. In both Exp. 2 and 3, the same treatment structure was used. As a split plot design, the main plot was the sow treatment from Exp. 1 (0 and 1000 ppm of CSB supplementation levels) and the subplot was the CSB supplementation levels in the nursery diet as follows: 1) basal diet with 0 ppm of CSB supplementation (control), 2) basal diet+500 ppm of CSB supplementation, and 3) basal diet+1000 ppm of CSB supplementation. All pigs were housed in raised-deck nursery pens (1.22×1.22 m^2) with water nipples, plastic feeders, and plastic coated expanded metal flooring. Feed and water were provided on an ad libitum basis. All pigs in Exp. 2 were injected intramuscularly at weaning with 4 mg of ovalbumin (Grade VII, Sigma Chemical, St. Louis, MO, USA) suspended in 1 mL of a 1:1 (volume/volume) solution of PBS and Freunds' incomplete adjuvant (Sigma Chemical) into the trapezius muscle. As an immune challenge, pigs were reinjected at d 14 postweaning. There was no immune challenge in Exp. 3.

Table 1
Formulas and chemical composition of experimental diets in gestation and lactation (g/kg as-fed basis, Exp. 1).[a]

Item	Gestation	Lactation
Ingredients		
Maize	833.2	675.5
Soybean meal (dehulled, 48% crude protein)	100.5	256.0
Alfalfa meal	25.0	25.0
Choice white grease	10.0	10.0
Dicalcium phosphate	15.5	12.1
Limestone (ground)	8.3	8.9
Salt (plain)	5.0	5.0
Vitamin premix[b]	1.0	1.0
Mineral premix[c]	0.5	0.5
Choline chloride (50%)[d]	1.0	1.0
Dynamate[e]	0.0	5.0
Total	1000.00	1000.00
Chemical composition[f]		
Metabolizable energy (MJ/kg)	13.85	13.79
Crude protein	121.1	181.9
Total Lys	5.4	9.7
SID[g] Lys	4.5	8.4
Total Ca	7.5	7.3
Total P	6.0	6.0

[a] Coated sodium butyrate (CM3000, Hangzhou King Techina Feed Co., Ltd., China) was added to the diet at the assigned levels as mentioned in the material and methods section.
[b] Supplied per kg of diet: vitamin A, 6600 IU; vitamin D_3, 1320 IU; vitamin E, 66 IU; vitamin K (as menadione sodium bisulfite complex), 6.6 mg; riboflavin, 8.8 mg; pantothenic acid, 22 mg; niacin, 88 mg; vitamin B_{12}, 33 μg; d-biotin, 0.22 mg; folic acid, 1.3 mg; and pyridoxine, 6.6 mg.
[c] Supplied per kg of diet: Zn, 100 mg as ZnO; Fe, 120 mg as $FeSO_4{\cdot}H_2O$; Mn 45 mg, as MnO; Cu, 12 mg as $CuSO_4{\cdot}5H_2O$; I, 1.5 mg as CaI_2O_6; and Se, 0.30 mg as $NaSeO_3$.
[d] Provides 500 mg choline per kg of diet as choline chloride.
[e] The product contained 180 g of K, 110 g of Mg, and 220 g of S per kg (Mosaic Feed Ingredients, FL, USA).
[f] Calculated values.
[g] Standardized ileal digestible.

2.2. Experimental diets and diet mixing procedures

2.2.1. Experiment 1

A corn-SBM-based diet was formulated to meet or exceed NRC (1998) nutrient requirement estimates during gestation and lactation (Table 1). The basal diets in gestation and lactation contained 13.85 and 13.79 MJ/kg of metabolizable energy (ME), 121.1 g/kg and 181.9 g/kg of crude protein, and 5.4 and 9.7 g/kg of total lysine, respectively. For diet mixing, large quantities of the basal diets were mixed and subdivided to which the additive (CSB) was applied; this prevented differences in nontreatment components of the diets. Specifically, a single batch of the basal diet was prepared and then divided into 2 fractions. One of the half fractions was blended with CSB for the diet containing the greatest level of CSB (1000 ppm) and another one remained unblended (control diet). To make the intermediate diet (500 ppm), a part of the concentrated portion was blended with an equal amount of the unblended basal diet.