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Dietary supplementation of sodium butyrate for mixed-parity sows during lactation

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ABSTRACT

The aim of this study was to evaluate dietary supplementation of sodium butyrate for mixed-parity sows during lactation on reproductive performance, milk composition, blood parameters and litter performance. A total of 192 sows were distributed in a completely randomized design in a 4 × 4 factorial arrangement, considering 4 experimental diets (diet without sodium butyrate, diet with 0.1% and 0.2% coated sodium butyrate, and diet with 0.066% uncoated sodium butyrate) and 4 parity order groups (1st, 2nd, 3rd and 4th, 5th to 7th), totaling 16 treatments with 12 replicates each, considering each sow and their litter as experimental unit. Dietary supplementation of sodium butyrate did not influence the reproductive performance of sows and productive performance of piglets during lactation ($P > 0.05$). There was an effect of parity orders on body weight at farrowing and weaning, average daily feed intake and estimated daily milk production of the sows ($P < 0.05$). There was influence of the different parity orders on litter weight at 48 h post-farrowing and at weaning, and also on the daily weight gain of the litter ($P < 0.05$). There was no interaction between the sodium butyrate supplementation and the different parity orders on blood parameters of sows ($P > 0.05$). There was interaction between the supplementation of sodium butyrate and the parity orders in caprylic, myristic and arachidonic acids in the milk of sows ($P < 0.05$). The butyric acid (C4:0) in the milk was influenced by dietary supplementation of sodium butyrate and parity orders ($P < 0.05$). Dietary supplementation of coated and uncoated sodium butyrate for lactating sows modifies the milk fatty acid profile, but does not affect the performance and blood parameters of sows, nor the performance of their progenies during lactation. Sows of 5th to 7th parity have better productive performance and heavier litter at 48 h post-farrowing and at weaning when compared to primiparous sows.

1. Introduction

The reproductive performance of sows and growth performance of neonatal piglets are fundamental to the development of pig farming. The current commercial genetic lines of sows have very satisfactory productive characteristics, such as high prolificacy and milk production. However, this genetic gain has generated some negative aspects, such as low voluntary feed intake and high capacity of corporal mobilization of sows, which may negatively affect the performance of these females and their litter.

Aiming to solve these inherent failures in pig farming advances, many researches involving the nutrition of pregnant and lactating sows have been performed, with focus on additives, such as butyric acid.

Butyric acid is a short chain fatty acid produced by microbial fermentation in the large intestine of the animals (Bergman, 1990). In the gastrointestinal tract, it acts by inhibiting the colonization and proliferation of pathogenic microorganisms, improving the integrity of the intestinal mucosa and, consequently, absorption of nutrients, which can significantly enhance animal performance (Guilloteau et al., 2010; Huang et al., 2015; Sengupta et al., 2006). However, because of its characteristics at room temperature, its use in pig diets occurs as butyrate, because it is present in the solid form, is more stable, less volatile and produces fewer odors, with sodium butyrate being the most used form.

Gálfi and Bokori (1990) noted positive influence of sodium butyrate on body weight gain, nutrient utilization and intestinal microflora composition in growing pigs. Since then, several studies have demonstrated the effects of this additive for pigs, especially in piglets diets

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during the nursery phase (Le Gall et al., 2009; Lu et al., 2008; Mazzoni et al., 2008; Fang et al., 2014). However, studies evaluating the dietary supply of sodium butyrate for lactating sows and its possible effects on their progeny are scarce and the results have been variable (Jang et al., 2017; Lu et al., 2012). In addition, no information about the different forms of sodium butyrate supply (coated vs. uncoated) is provided. Therefore, the aim of this study was to evaluate the coated and uncoated sodium butyrate supplementation in diets for mixed-parity sows during lactation on performance, milk composition and blood parameters, as well as the performance of suckling piglets.

2. Material and methods

The experiment was conducted under protocol approved by the Committee of Ethic in Animal Research of the Federal University of Ceará and followed guidelines stated in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 2010).

A total of 192 mixed-parity sows of a high-prolificacy commercial genetic line (Landrace × Large White) were distributed in a completely randomized design in a 4 × 4 factorial arrangement, considering 4 parity orders (1st, 2nd, 3rd and 4th, 5th to 7th calving) and 4 experimental diets, totaling 16 treatments with 12 replicates each, considering each sow and their litter as experimental unit. The following experimental diets were applied: control diet without sodium butyrate; diet with 0.1% and 0.2% coated sodium butyrate; and diet with 0.066% uncoated sodium butyrate.

The diets were formulated to meet the nutritional requirements of lactation sows, according to the recommendations contained in the lineage manual (Table 1). Sodium butyrate was incorporated into the diet by adding the commercial feed additive (Adimix®, Nutriad).

At 110 days of gestation, sows were individually weighed and the backfat thickness was measured at point P2, obtained at 6.5 cm from the dorso-lumbar line and at 6.5 cm from the last rib by ultrasound device (Preg-Tone, Renco®).

Up to 48 h postpartum, the piglets were weighed and the litters were standardized to 13 piglets among the sows of the same treatment. During the experimental period, the dead piglets were weighed to estimate the development of litter and milk production. During the lactation period, piglets had no access to creep feed and water was available ad libitum through a bite-ball nipple drinker.

The dietary treatments were offered after farrowing and were then submitted to a step-up feeding regime to stimulate gradual feed intake increase up to day 8 post-farrowing, starting at 2.0 kg on day 1 post-farrowing and reaching 9.0 kg on day 8, remaining constant until weaning. The average daily feed intake was determined by the difference between the feed allowance and the refusals collected daily. The body loss of sows was estimated from the empty live weight (ELW, kg) and backfat thickness (P2, mm) according to the equations proposed by Dourmad et al. (1997): Protein (kg) = 2.28 (± 2.22) + 0.178 (± 0.017) ELW − 0.333 (± 0.067) P2 and Lipid (kg) = −26.4 (± 4.5) + 0.221 (± 0.030) ELW + 1.331 (± 0.140) P2. The estimation of daily milk production (DMP) was based on litter weight gain (LWG), number of piglets and milk dry matter (19%), according to the equation of Noblet and Etienne (1986): DMP (kg/day) = ([0.718 * LWG − 4.9] * No. of piglets)/0.19.

Four sows were selected from each treatment, according to body weight and fat thickness at the beginning of the experimental period, to collect blood and milk samples. Blood samples were taken on the 14th day of lactation through the jugular vein, 2 h after feeding, for the determination of glucose, triglycerides and non-esterified fatty acids. Glucose determination was performed using a glycosimeter composed of a reflectometer and reagent strips. Immediately after collection, the samples were centrifuged at 3000 × *g* for 5 min at room temperature and supernatant was removed, stored in properly identified tubes, and stored in a freezer at −20 °C for subsequent analyzes. The methodology for triglycerides was enzymatic colorimetric, using commercial kits (Labtest Diagnóstica®, ref.: 87). The non-esterified fatty acids were determined using Randox Monza® clinical chemistry analyzer by Randox NEFA kit (Ref.: FA115).

On the 18th day of lactation, milk samples of approximately 200 mL were collected manually from all active teats on each sow by injecting 1.0 mL of oxytocin into the auricular vein. The milk was homogenized and stored in duplicate in sterile containers at −20 °C for subsequent analyzes. Chemical composition of milk was performed using the Lactoscan Milk Analyzer®, to determine the density and the contents of dry matter, lipid, protein and lactose. To determine the fatty acid profile, the methyl esters were prepared from the fatty acid esters and glycerol of milk fat by hydrolysis and esterification, according to the methodology of Adolfo Lutz Institute (2005). The methyl esters obtained were further analyzed by gas chromatography.

Weaning occurred after 24 days of lactation. At this moment, the piglets of each litter were counted and the litter was weighed. After

Table 1
Calculated and nutritional composition of experimental diets for sows in the lactation phase.

Item (%)	Control[a]	0.1% coated SB[b]	0.2% coated SB	0.066% uncoated SB
Corn, grain	53.713	53.713	53.713	53.713
Soybean meal 45%	13.500	13.500	13.500	13.500
Extruded whole soybeans	23.000	23.000	23.000	23.000
Salt	0.500	0.500	0.500	0.500
Limestone 38%	1.000	1.000	1.000	1.000
Dicalcium phosphate 18%	1.700	1.700	1.700	1.700
DL-methionine 99%	0.140	0.140	0.140	0.140
L-lysine HCL 99%	0.300	0.300	0.300	0.300
L-threonine 98.5%	0.120	0.120	0.120	0.120
Choline chloride 70%	0.070	0.070	0.070	0.070
Copper sulfate pentahydrate 25%	0.057	0.057	0.057	0.057
Crystal sugar	5.000	5.000	5.000	5.000
Adsorbent	0.100	0.100	0.100	0.100
Imunotron®[c]	0.200	0.200	0.200	0.200
PX VM Swine Reprodction®[d]	0.300	0.300	0.300	0.300
Inert[e]	0.200	0.100	0.000	0.134
Coated sodium butyrate	–	0.100	0.200	–
Uncoated sodium butyrate	–	–	–	0.066
Total	100.000	100.000	100.000	100.000
Nutritional composition				
Metabolizable energy (kcal/kg)	3399.189	3399.189	3399.189	3399.189
Crude protein (%)	19.206	19.206	19.206	19.206
Ethereal extract (%)	7.159	7.159	7.159	7.159
Crude fiber (%)	3.295	3.295	3.295	3.295
Total available calcium (%)	0.991	0.991	0.991	0.991
Available phosphorus (%)	0.463	0.463	0.463	0.463
Sodium (%)	0.232	0.232	0.232	0.232

[a] Without sodium butyrate.
[b] Sodium butyrate.
[c] Imunotron: vitamin A (2,500,000 UI/kg), vitamin E (7500 UI/kg), biotin (75 mg/kg), zinc (130 g/kg), chelated zinc (20 g/kg).
[d] PX VM Swine Reproduction: vitamin A (1,500,000 UI/kg), vitamin D (226.667 UI/kg), vitamin E (6667 UI/kg), vitamin K3 (333.30 mg/kg), vitamin B1 (333.30 mg/kg), vitamin B2 (1167 mg/kg), vitamin B6 (416.60 mg/kg), vitamin B12 (5333.30 mg/kg), niacin (6000 mg/kg), pantothenic acid (3333.30 mg/kg), folic acid (400 mg/kg), biotin (32 mg/kg), manganese (8333.30 mg/kg), zinc (18.33 g/kg), iron (13.33 g/kg), copper (2333.30 mg/kg), iodine (266.70 mg/kg), selenium (100 mg/kg), chelated chrome (100 mg/kg), BHT (250 mg/kg).
[e] Inert: washed sand.

Table 2
Productive parameters of mixed-parity sows supplemented with coated and uncoated sodium butyrate during 24 days of lactation.

Parameters	Supplementation (Supp)				Parity order (PO)				RSD[c] (%)	*P*-value		
	Control[a]	0.1% coated SB[b]	0.2% coated SB	0.066% uncoated SB	1	2	3 e 4	5 a 7		Supp	PO	Supp*PO[d]
Average daily feed intake (kg)	5.25	5.66	5.53	5.55	5.32b	5.47ab	5.79a	5.68a	9.61	0.6136	0.0003	0.2080
Body weight (kg)												
After farrowing	226.04	227.34	224.22	226.37	188.08d	214.41c	238.24b	263.23a	8.59	0.9092	<0.0001	0.0695
At weaning	195.89	214.12	209.91	209.88	176.20d	196.40c	223.26b	248.94a	10.00	0.7839	<0.0001	0.3588
Backfat thickness (mm)												
After farrowing	16.93	16.26	16.37	17.11	16.42	16.69	16.16	17.42	16.49	0.4491	0.1494	0.1247
At weaning	14.08	14.17	13.85	14.53	13.88	13.41	14.37	15.01	19.32	0.7489	0.0551	0.3680
Body loss[e]												
Protein (kg)	15.27	15.47	18.48	17.66	13.72	17.47	17.83	17.56	74.83	0.6247	0.3169	0.0901
Lipid (kg)	3.88	3.31	4.14	4.36	3.48	4.93	3.14	4.13	114.24	0.7266	0.3506	0.4077
Weight loss[f] (%)	8.40	8.72	10.35	9.85	9.45	10.18	3.39	8.30	77.28	0.5719	0.6855	0.1447
WEI[g] (dias)	4.59	4.60	4.39	4.52	4.59	4.26	4.51	4.74	20.62	0.7841	0.2460	0.2231
DMP[h] (kg/dia)	12.82	11.96	12.34	12.44	11.19b	12.39ab	12.40ab	12.84a	18.16	0.7512	0.0023	0.0750

[a] Without sodium butyrate.
[b] Sodium butyrate.
[c] Relative standard deviation.
[d] Interaction between sodium butyrate supplementation and parity order.
[e] Estimated from the empty live weight (ELW, kg) and backfat thickness (P2, mm) according to the equations published by Dourmad et al. (1997): Protein (kg) = 2.28 (± 2.22) + 0.178 (± 0.017) ELW − 0.333 (± 0.067) P2; Lipid (kg) = −26.4 (± 4.5) + 0.221 (± 0.030) ELW + 1.331 (± 0.140) P2.
[f] Weight loss percentage.
[g] Weaning-to-estrus interval.
[h] Means followed by different letters on the same line differ by Tukey test ($P < 0.05$).

weaning, the sows were weighed and the backfat thickness was measured. Then, they were transferred to a gestation shed, where they continued to receive 3.0 kg/day of the respective experimental diets until they presented estrus, to determine the weaning-to-estrus interval (WEI).

The data were submitted to analysis of variance by General Linear Models procedure of the Statistical Analysis System (SAS University Edition), considering each sow and their litter as experimental unit, totaling 12 replicates per treatment. Means were compared by the Tukey Test at 5% of significance.

3. Results

There was no interaction ($P > 0.05$) between the supplementation of sodium butyrate and the different parity orders for productive parameters of sows (Table 2). Although no effect ($P > 0.05$) of dietary supplementation of sodium butyrate on productive parameters of sows was observed, there was influence of the different parity orders on average daily feed intake, body weight at farrowing and at weaning, and estimated daily milk production ($P < 0.05$). Primiparous sows had lower average daily feed intake than sows of 3rd to 7th parity ($P < 0.05$). Body weight at farrowing and at weaning increased as the parity order increased ($P < 0.05$). Sows of 5th to 7th parity had a higher estimated daily milk production than primiparous sows ($P < 0.05$).

No interaction was observed ($P > 0.05$) between the supplementation of sodium butyrate and the different parity orders on the performance of the litters (Table 3). The supplementation of sodium butyrate did not influence the performance of the litters ($P > 0.05$). However, for litter weight at 48 h post-farrowing and at weaning and, consequently, for the daily weight gain of the litter, elicited a response among the parity orders ($P < 0.05$).

There was no interaction ($P > 0.05$) between the sodium butyrate supplementation and the different parity orders on blood parameters of sows (Table 4). The isolated factors also did not influence the serum concentrations of glucose, triglycerides and non-esterified fatty of sows ($P > 0.05$).

There was interaction ($P < 0.05$) of sodium butyrate supplementation and the different parity orders in caprylic (C8:0), myristic (C14:0) and arachidonic (C20:4n6) acids in the milk (Table 5), but no interaction of the factors on chemical composition of milk was noted ($P > 0.05$). The butyric acid (C4:0) in the milk was influenced by dietary supplementation of sodium butyrate ($P < 0.05$). Sows fed diets with 0.2% coated sodium butyrate and 0.066% uncoated sodium butyrate had the highest content ($P < 0.05$) of this fatty acid in the milk in relation to sows fed with control diet (Table 5). The parity order also

Table 3
Litter performance from mixed-parity sows supplemented with coated and uncoated sodium butyrate during 24 days of lactation.

Parameters	NP48h[a]	NWP[b]	WL48h (kg)[c]	WLW (kg)[d]	LDWG (kg/d)[e]
Supplementation					
Control[f]	12.83	12.00	19.09	73.70	2.59
0.1% coated SB[g]	12.85	11.93	19.24	74.67	2.55
0.2% coated SB	13.03	12.26	18.72	74.75	2.59
0.066% uncoated SB	12.95	11.86	18.96	74.48	2.65
Parity order (PO)					
1	12.87	12.07	17.21b	69.54b	2.38b
2	12.82	11.98	19.27ab	75.44ab	2.65a
3 e 4	12.95	11.91	19.00ab	75.07ab	2.64a
5 a 7	12.99	12.08	20.51a	77.55a	2.71a
RSD[h] (%)	4.36	7.75	17.39	13.97	15.64
P-value					
Supplementation	0.2170	0.2343	0.9144	0.9697	0.7302
Parity order	0.4906	0.8173	<0.0001	0.0016	0.0004
Supplementation *PO[i]	0.6335	0.0978	0.0632	0.1533	0.0875

[a] NP48h: number of piglets standardized at 48 h.
[b] NWP: number of weaned piglets.
[c] WL48h: weight of standardized litter at 48 h.
[d] WLW: weight of litter at weaning.
[e] LDWG: litter daily weight gain.
[f] Without sodium butyrate.
[g] Sodium butyrate.
[h] Relative standard deviation.
[i] Interaction between sodium butyrate supplementation and parity order. Means followed by different letters on the same column differ by Tukey test ($P < 0.05$).

Table 4
Blood parameters of mixed-parity sows supplemented with sodium butyrate.

Parameters	Glucose (mg/dL)	Triglycerides (mg/dL)	NEFA[a] (mmol/L)
Supplementation			
Control[b]	83.07	124.27	0.17
0.1% coated SB[c]	80.61	139.21	0.17
0.2% coated SB	85.50	128.23	0.21
0.066% uncoated SB	78.00	129.06	0.23
Parity order (PO)			
1	83.92	129.36	0.17
2	81.86	125.80	0.17
3 e 4	79.20	130.37	0.20
5 a 7	82.71	131.35	0.21
RSD[d] (%)	18.53	13.46	70.03
P-value			
Supplementation	0.6155	0.0948	0.5857
Parity order	0.8603	0.9254	0.7057
Supplementation *PO[e]	0.9028	0.0564	0.8206

[a] Non-esterified fatty acids.
[b] Without sodium butyrate.
[c] Sodium butyrate.
[d] Relative standard deviation.
[e] Interaction between sodium butyrate supplementation and parity order. Means followed by different letters on the same column differ by Tukey test ($P < 0.05$).

Table 6
Interactions between sodium butyrate supplementation and parity order on caprylic, myristic and arachidonic acids in sow's milk.

Supplementation	Parity order 1	2	3 e 4	5 a 7
Caprylic acid (C8:0)				
Control[a]	0.004	0.015	0.015	0.011
0.1% coated SB[b]	0.008	0.009	0.000	0.012
0.2% coated SB	0.015ab	0.044a	0.010b	0.006b
0.066% uncoated SB	0.024	0.019	0.011	0.008
Myristic acid (C14:0)				
Control	3.031	1.447B	2.541	3.285
0.1% coated SB	3.367	3.583AB	2.180	2.550
0.2% coated SB	3.804	1.780B	3.929	3.639
0.066% uncoated SB	3.111ab	9.121aA	3.038b	3.577ab
Arachidonic acid (C20:4n6)				
Control	0.005	0.067	0.036	0.044
0.1% coated SB	0.069	0.025	0.029	0.035
0.2% coated SB	0.059ab	0.119ab	0.119a	0.021b
0.066% uncoated SB	0.038	0.027	0.055	0.041

[a] Without addition of sodium butyrate.
[b] Means followed by different letters, capital for column and lowercase for line, differ by Tukey test ($P < 0.05$).

influenced the C4:0 content of milk ($P < 0.05$), where primiparous sows had a lower value of this fatty acid than sows of 3rd to 7th parity.

Regarding the interaction between sodium butyrate supplementation and parity order (Table 6), it was found that the first and second parity orders sows, which received 0.2% coated sodium butyrate, had

Table 5
Chemical composition and fatty acid profile of milk of mixed-parity sows supplemented with coated and uncoated sodium butyrate.

Parameters	Supplementation (Supp) Control[a]	0.1% coated SB[b]	0.2% coated SB	0.066% uncoated SB	Parity order (PO) 1	2	3 e 4	5 a 7	RSD[c] (%)	*P*-value Supp	PO	Supp*PO[d]
Milk composition												
Dens[e] (g/cm³)	1.06	1.06	1.05	1.05	1.06	1.07	1.06	1.04	3.69	0.5067	0.1294	0.1056
Dry matter[f] (%)	20.21	20.15	20.01	19.72	20.10	20.02	20.03	19.94	5.48	0.6987	0.9811	0.6975
Lipid (%)	11.33	11.41	10.92	10.80	11.00	11.23	11.19	11.04	8.07	0.2552	0.8992	0.5613
Protein (%)	6.04	5.90	5.98	5.93	5.98	5.98	5.95	5.93	4.84	0.6500	0.9432	0.9085
Lactose (%)	5.26	5.29	5.22	5.28	5.22	5.29	5.30	5.24	5.01	0.4546	0.8168	0.4006
Saturated fatty acids												
Total (%)	34.35	30.12	32.38	37.87	38.82	32.22	30.10	33.58	35.74	0.4273	0.3044	0.2265
C4:0	4.61c	5.38bc	8.47ab	9.62a	4.67b	7.14ab	7.94a	8.32a	42.35	0.0003	0.0141	0.9924
C6:0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	125.09	0.6474	0.4356	0.4879
C8:0	0.01	0.01	0.02	0.01	0.01ab	0.02a	0.009b	0.009b	90.92	0.0449	0.0308	0.0265
C10:0	0.07	0.09	0.08	0.11	0.11	0.07	0.09	0.07	54.84	0.2152	0.1573	0.1942
C12:0	0.13	0.15	0.14	0.14	0.16	0.13	0.14	0.13	56.89	0.9554	0.7581	0.8825
C14:0	2.57	2.92	3.28	4.71	3.32	3.98	2.92	3.26	58.41	0.0433	0.6501	0.0495
C16:0	9.41	9.57	8.20	8.82	9.80	9.00	7.97	9.24	30.29	0.5757	0.3392	0.2799
C18:0	6.72	4.75	5.28	5.27	6.91	5.04	4.44	5.64	57.00	0.4353	0.2294	0.5503
C20:0	0.08	0.15	0.07	0.04	0.11	0.09	0.04	0.10	110.07	0.0543	0.2276	0.5502
Monounsaturated fatty acids												
Total (%)	33.75	35.31	37.25	35.56	31.78	37.00	36.69	36.40	21.51	0.7191	0.2975	0.1981
C14:1	0.11	0.14	0.12	0.15	0.17	0.11	0.14	0.11	61.68	0.7443	0.2275	0.9700
C16:1	6.43	7.50	7.28	8.10	7.60	4.94	8.64	8.12	45.58	0.6955	0.1104	0.3370
C18:1n9	24.00	22.82	26.50	24.88	22.00	28.17	22.70	25.34	24.64	0.4707	0.0909	0.4261
C20:1n9	0.14	0.09	0.14	0.11	0.11	0.15	0.09	0.13	78.67	0.4046	0.3831	0.2384
Polyunsaturated fatty acids												
Total (%)	31.91	35.11	30.42	26.57	29.46	30.79	32.53	31.24	31.57	0.2090	0.8793	0.7798
C18:2n6	23.00	27.29	26.04	22.09	23.88	24.06	24.77	25.70	45.05	0.6199	0.9689	0.7509
C18:3n6	0.05	0.10	0.14	0.09	0.09	0.09	0.09	0.10	78.95	0.0652	0.9952	0.2452
C18:3n3	2.57	2.24	2.94	2.23	3.39	1.90	2.26	2.42	69.93	0.7152	0.2480	0.1942
C20:2	0.17	0.24	0.26	0.23	0.17	0.28	0.23	0.21	68.07	0.4953	0.4521	0.7030
C20:3n6	0.08	0.07	0.08	0.04	0.06	0.09	0.06	0.06	79.89	0.1958	0.5309	0.2484
C20:3n3	0.13	0.21	0.18	0.16	0.21	0.18	0.15	0.15	74.96	0.4556	0.6256	0.1864
C20:4n6	0.03	0.03	0.08	0.04	0.04	0.05	0.06	0.03	83.46	0.0244	0.2179	0.0326

[a] Without sodium butyrate.
[b] Sodium butyrate.
[c] Relative standard deviation.
[d] Interaction between sodium butyrate supplementation and parity order.
[e] Density.
[f] Means followed by different letters on the same line differ by Tukey test ($P < 0.05$).

the highest levels of caprylic acid (C8:0) in milk than the other sows receiving the same supplementation ($P < 0.05$). The supplementation of 0.066% uncoated sodium butyrate influenced the myristic acid content (C14:0), and the amount of C14:0 present in the milk of the 2nd parity order sows differed from those of the 3rd and 4th parity order ($P < 0.05$). In addition, it was possible to observe the effect of sodium butyrate supplementation on 2nd parity order sows, which sows receiving 0.066% uncoated sodium butyrate had the highest content of myristic acid in milk in relation to that which received 0.2% coated sodium butyrate and those that received diet without sodium butyrate ($P < 0.05$). The content of arachidonic acid (C20:4n6) in the milk of sows was influenced by dietary supplementation of 0.2% coated sodium butyrate, since the content of this fatty acid in the milk of the 3rd and 4th parity order sows differed from the sows of 5th to 7th parity order ($P < 0.05$).

4. Discussion

In relation to sodium butyrate supplementation, the results observed for productive parameters of sows corroborate with Jang et al. (2017), who also did not verify the effect of sodium butyrate supplementation on body weight and feed intake of lactating sows.

The lack of response in sow performance may be associated with the short duration of sodium butyrate supply, since it was provided for sows only during lactation, not influencing farrowing weight. However, it was expected that sodium butyrate could positively affect sows body weight at weaning, as this additive beneficially modulates the intestinal microbiota, which may contribute to better utilization of the feed nutrients.

The effect of parity order on average daily feed intake is justified by the tissue development still observed in sows until the 2nd parity order. Therefore, they present lower feed intake capacity when compared to mixed-parity sows (Young et al., 2004). In this sense, older sows are heavier and are expected to ingest more feed due to the higher requirement of maintenance during lactation (Eissen et al., 2000).

Due to the importance of lactation in reproductive cycle of sows, it is essential to provide a diet capable of reducing excessive loss of body weight and backfat thickness at this phase. Thus, it was expected that sows receiving sodium butyrate supplementation could maintain body integrity as result of the better utilization of the feed nutrients. However, no significant difference was observed in backfat thickness, body loss and weight loss percentage between sows receiving sodium butyrate supplementation and those receiving control diet.

Increased weight loss during lactation may be associated with increases in weaning-to-estrus interval, because negative energy balance modifies blood metabolites, which may cause inhibition of luteinizing hormone secretion (Mellagi et al., 2010a; Ulguim et al., 2013). However, the fact that weaning-to-estrus interval was not influenced by the treatments in the present study is in agreement with the results of studies performed from the last decade, which show that in modern genotypes this parameter is not always influenced by the degree of lactational catabolism (Mejia-Guadarrama et al., 2002; Schenkel et al., 2010; Vinsky et al., 2006).

In relation to estimated DMP, primiparous sows have a productive genetic potential similar to mixed-parity sows. However, it was observed that sows of 5th to 7th parity had a higher estimated daily milk production than primiparous sows. The parity order may affect the distribution of energy and protein between maternal and breast tissue during lactation, since young females require nutrients for body growth (Mellagi et al., 2010a), including to mammary system.

Regarding the litter performance, the results observed in the present study is similar to that reported by Wang et al. (2014) and Jang et al. (2017), which did not observed difference in piglet development from sows supplemented with sodium butyrate during the lactation. However, it was expected that dietary supplementation of sodium butyrate for sows could favor the daily milk production due to better utilization of dietary nutrients, which would result in better performance of their litter.

The effects of parity orders on litter weight at 48 h post-farrowing, at weaning and daily weight gain of litter are in accordance with Martins et al. (2007), whose affirmed that the lower weight gain of piglets from primiparous sows is due to the lower intake of the main nutrients present in the milk of these sows. The metabolic state of sow during lactation is influenced by factors such as the amount of nutrients absorbed and the amount of body reserves (Bierhals et al., 2011). In addition, the mobilization of body reserves in primiparous sows is not always able to compensate for protein deficit (Revell et al., 1998). Due to the lower feed intake, a compromise can occur on milk production and, consequently, on the performance of litter.

Values below 85 mg/dL for serum glucose found in the present study are justified by the fact that glucose in lactating sows is used to meet the maintenance energy of the mammary gland and is a primary precursor for lactose synthesis (Mellagi et al., 2010b). With the use of additives capable of improving the utilization of dietary nutrients, such as sodium butyrate, the metabolites used in milk synthesis are expected to come largely from the diet. Therefore, the low quantifying of non-esterified fatty acids suggests that the use of fatty acids for milk synthesis occurs mainly from blood triglycerides, since the contribution of non-esterified fatty acids as precursor to milk synthesis is important at the beginning of lactation and in numerous litters, when the negative energy balance and the mobilization of body fat occur (Mellagi et al., 2010b).

It was observed that dry matter and lipid values were higher than those observed by Alston-Mills et al. (2000) and Martins et al. (2007), however, the values of protein and lactose were similar to those obtained by the aforementioned authors. Alston-Mills et al. (2000) considered that the component of greater variation in sow´s milk is lipid, which explains the difference of the values of this compound.

Although the quantitative contribution of preformed fatty acids to the synthesis of milk fat in the lactating sow is not known, it is established that only lipid fraction in the blood that has significant uptake by the mammary gland is the triglyceride fraction (Daves and Bauman, 1974). Therefore, the fatty acids present in milk tend to reflect the fat composition of the diet, according to Mcnamara (1997).

The butyrate contribution for milk synthesis in sows is not well understood. It is known that, among the short chain fatty acids, the mammary gland mainly oxidizes acetate and, according to Nelson and Cox (2011), the butyrate, when oxidized, is transformed into Acetyl co-A, which, in turn, can enter the tricarboxylic acid cycle and be transformed into ketone bodies or acetate. In lactating sows, acetate production is higher than ketone bodies, since plasma acetate levels are 5-fold higher than β-hydroxybutyrate levels (Theil et al., 2013).

Thus, the observed modulation of fatty acids present in milk may be beneficial for suckling piglets, since short chain fatty acids, such as butyric acid (C4:0), and medium chain fatty acids, such as caprylic acid (C8:0) and myristic acid (C14:0), are more digestible and can be absorbed and oxidized more efficiently by the piglets (Chiang et al., 1990; Gu and Li, 2003; Manzke et al., 2004; Zentek et al., 2011), being used as energy source for these animals. In addition, the polyunsaturated omega-6 fatty acids, such as arachidonic acid (C20:4n6), are precursors of eicosanoids, molecules involved in the inflammatory process and formation of clots (Perini et al., 2010), important in body protection against infections and injuries.

5. Conclusion

Dietary supplementation of coated and uncoated sodium butyrate for lactating sows modulates the milk fatty acid profile, but does not influence the performance of sows and piglets at lactation phase. Primiparous sows have lower productive performance and lighter litter when compared to sows of 5th to 7th parity order.

Declaration of Competing Interest

None.

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