THE INFLUENCE OF SODIUM BUTYRATE AND VEGETABLE FATTY ACIDS ON PRODUCTIVITY AND MEAT QUALITY OF FATTENING PIGS

Asta Racevičiūtė-Stupelienė[1], Vilma Šašytė[1], Vilma Vilienė[1], Saulius Alijošius[1], Virginijus Slausgalvis[2], Stephan Bauwens[2], Jolita Klementavičiūtė[1], Monika Nutautaitė[1], Vilija Buckūnienė[1], Mindaugas Paleckaitis[1]

[1]Institute of Animal Rearing Technologies, Veterinary Academy, Lithuanian University of Health Sciences Tilzes str. 18, LT-47181 Kaunas, Lithuania; e-mail: asta.raceviciutestupeliene@lsmuni.lt, phone/fax: +370 37 363505
[2]Innov ad nv/sa, Postbaan 69, 2910 *Essen, Belgium*

**Corresponding author: Asta Racevičiūtė-Stupelienė*
Lithuanian University of Health Sciences, Tilzes str. 18, 47181, Kaunas, Lithuania
Phone: +370 37 36 35 05; e-mail: asta.raceviciutestupeliene@lsmuni.lt

Abstract. The aim of this study was to determine the effect of sodium butyrate and vegetable fatty acids on productivity parameters and meat quality of fattening pig. The feeding trial was started with 40 day old (hybrid (mother) and Yorkshire (father)) fattening pigs, which were individually weighed and were randomly assigned to two dietary treatments with four replicate stalls of 16 fattening pigs each. The pigs of control and experimental groups were fed *ad libitum* with a standard wheat-barley-soybean meal compound diet, just experimental group supplemented with a mixture of sodium butyrate and vegetable fatty acids (dosage 2 kg/t of feed). Meat traits in live pigs were measured by ultrasonic equipment Piglog 105. All samples were taken from the *M. longissimus dorsi* between 12 and last rib. The analysis of cholesterol and chemical composition was determined by standard methods. During all experimental period (from 40 till 156 days), the inclusion of 2.0 kg/t sodium butyrate and vegetable fatty acids in the diets of fattening pigs had tendency to increase the weight and daily gain of pigs by 5%, gain ratio by 12% and cholesterol levels by 5% compared to the control group, but no significant differences between groups were determined.

Keywords: fattening pigs, sodium butyrate, vegetable fatty acids, productivity, meat quality

Introduction. Fats and oils have assumed considerable importance as raw materials in animal feed due to their ability to provide energy. Nutritionally they are concentrated sources of energy, providing essential fatty acids that are the building blocks for hormone-like compounds and are carriers for the liposoluble vitamins A, D, E, and K. Moreover, their physical textures reduce dustiness in feed mills and increase diet flavor (Wiseman and Garnsworthy, 1997). In intestine of human and animals butyrate is produced by microbial fermentation. It serves many things – primary nutrient that provides energy to colonocytes, also it is a cellular mediator regulating multiple functions of gut cells and beyond, including gene expression, cell differentiation, gut tissue development, immune modulation, oxidative stress reduction, diarrhea control. Butyrate and its derivatives generally demonstrate positive effects not just in large amount studies in human medicine, but also on animal production, including enhancement of gut development, control of enteric pathogens, reduction of inflammation, improvement of growth performance and modulation of gut microbiota. The importance of butyrate in maintaining gut health has also attracted significant research attention to its application for animal production, particularly as an alternative to in-feed antibiotics. Using butyrate in practice sometimes has difficulties, because of its offensive odor and absorption in the upper gut. But different forms of butyrate, such as sodium butyrate have been developed and researched for their influence on gut health and growth performance on pork.

One of critical time periods for piglets is the weaning transition. There are main causes like shifting feed from liquid to solid, changes in environment, mixing with new pen mates are stressful and often can cause a post-weaning growth lag. Important factor in this growth lag is the underdeveloped gastro intestine tract due to early weaning and it affects inappropriate digestion and nutrients absorption (Thacker, 2013).

Early studies of influence of organic acids embedded in the diets of weaned pigs has shown that organic acids can improve growth performance, and increase digestibility (Henry et al., 1985). Later study about butyrate was reported by Piva et al. (2002a,b). Results showed that piglets fed sodium butyrate had a distinctly higher average daily gain after 14 days of treatment compared to control pigs. It is concluded that this has happened due to positive effect of butyrate on cell proliferation of the intestinal epithelium, which has greater biological value in the early weaning period when intestine (small and large) are rapidly increasing in size. Pigs fed the sodium butyrate diet had also increased feed intake compared to control pigs without sodium butyrate diet and treatment lasted 35 days.

The objective of this study was to determine the influence of sodium butyrate and vegetable fatty acids on productivity and meat quality of fattening pigs.

Materials and Methods

The trial with pigs for fattening were conducted following the regulations of the Republic of Lithuania (2013-01-01 new edit of 1997-11-06) for animal welfare and handling (Valstybės žinios, 2012, No. 122 - 6126) and by the State Food and Veterinary Service of Lithuanian Republic Ditector order regarding the animals used for experiments, research, storage, maintenance and

operating requirements (2015-09-24, No. B1-872 change by order 2012-10-31, No. B1-866). The trial performed in accordance with EU Directive 2010/63/EEC and the EC recommendation 2007/526 EC for Animal use and storage for experiments and other purposes. The pigs for fattening were kept in the stalls and its keeping condition was accorded with the Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs.

The feeding trial was started with 40-day old (hybrid (mother) and Yorkshire (father)) pigs for fattening which were individually weighed and were randomly assigned to 2 dietary treatments with 4 replicate stalls of 16 fattening pigs each. Pigs were fed *ad libitum* a standard wheat-barley-soybean meal compound diet (Control group) supplemented with a mixture of sodium butyrate and vegetable fatty acids (dosage 2 kg/t of feed, Experimental group). The composition and calculated values of the basal diet are shown in Table 1. The diet was formulated to match the nutrient and energy requirements for pigs for fattening (NRC, 2012). The content of crude protein, crude fat, crude fibre, crude ash, calcium and phosphorus was determined with near infra-red reflectance spectroscopy (NIRS). The data recorded during the feeding phase were live weight (LW) at 40, 74, 102, 135 and 156 day from the start of the study, average daily gains (ADG) and feed: gain ratio (F:G) during the periods 40-74 days, 74-102 days, 102-135 days, 135-156 days and from the start of the study (40–156 days).

Table 1. **Composition and calculated values of the basal diet**

Ingredients	**Components (%)**	
	First growing period (30–60 kg)	**The second growing period (60–110 kg)**
Barley	35.300	45.610
Wheat	23.064	14.401
Triticale	20.000	20.000
Soybean meal	14.683	11.129
Rape cake	4.000	6.000
Feed limestone R1	1.422	1.353
Vegetable oil	0.500	0.500
Salt NaCl	0.350	0.380
Lysine HCL	0.319	0.328
Monocalcium phosphate	0.100	0.050
Threonine	0.084	0.077
Methionine 99%	0.028	0.023
Mineral-vitamin mixture for fattening pigs**	0.130	0.130
Rovabio Exel LC2	0.012	0.012
Phytase EC 5L Liquid	0.012	0.012
All in	**100**	**100**
Calculated values, %		
ME (metabolized energy), MJ/kg	13.10	13.00
Crude protein*	17.00	16.00
Crude fat*	2.43	2.59
Crude fibre*	4.17	4.68
Crude ash*	4.92	4.84
Lysine	0.99	0.95
Methionine+cystine	0.58	0.56
Methionine	0.28	0.27
Threonine	0.63	0.60
Tryptophan	0.22	0.20
Calcium*	0.68	0.65
Phosphorus*	0.44	0.44
Sodium	0.17	0.19
* Analysed values; **Premix composition: vit. A – 7 000 IU; vit. D_3 – 1 500 IU; vit. E – 60 mg/kg; vit. K_3 – 2.00 mg/kg; vit. B_1 – 2.00 mg/kg; vit. B_2 – 7.00 mg/kg; vit. B_6 – 2.50 mg/kg; vit. B_{12} – 30.00 µg/kg; nicotinic acid – 20.00 mg/kg; pantothenic acid – 25.00 mg/kg; folic acid – 1.00 mg/kg; biotin – 200.00 µg/kg; iron– 60.00 mg/kg; manganese – 28.12 mg/kg; zinc – 150.00 mg/kg; copper – 25.00 mg/kg; iodine – 1.50 mg/kg; selenium – 0.30 mg/kg.		

Characteristics of pigs measured before slaughtering: the thickness of the *M longissimus dorsi* (mm), fat thickness at the waist area was measured at the 3rd lumbar vertebra and 7 cm from middle back line towards the underbelly (FAT-1), and 10 cm from the last rib edge to the cranial side (FAT-2). These measurements were made

with ultrasound equipment „Piglog-105'' (SFK Technology, 1991).

At the end of the trial (156 days) from each group 8 pigs for fattening (8 pigs x 2 groups = total of 16 pigs) were selected and slaughtered according to standard procedures. Established physical characteristic: meat color by a Minolta Chroma-meter (CR-410, Konica Minolta, Osaka, Japan) in the CIE L* a* b* space. The L* value indicates the lightness, representing dark to light (0–100). The a* (redness) value gives the degree of the red–green colour, with a higher positive a* value indicating more red colour. The b* (yellowness) value indicates the degree of the yellow–blue colour, with a higher positive b* value indicating more yellow colour. White calibration with the specifications of Y=86.2, x=0.3160 and y=0.3231 was used to standardise the chroma-meter. Other parameters of muscles were analysed as following steps: cooking losses of the meat by cooking the meat in a circulating bath at 70 °C according to the change in weight of the meat samples before and after cooking; water-holding capacity by the method of Grau and Hamm (1956); drip loss by the decrease in weight of the meat sample keeping for 24 hours at + 4 °C in special reticulate bags and was calculated as the percentage of weight lost; meat tenderness according to the Warner Bratzler (1949) test.

After slaughter 1, 24, 48, and 72 hours, muscle pH of *M. longissimus dorsi* was examined using "Inolab 730".

Chemical composition of breast meat was determined by standard methods (AOAC, 1990).

The concentration of cholesterol in the *M. longissimus dorsi* was determined by high performance liquid chromatography method described by Polak (Polak et al., 2008). For this purpose, a high pressure gradient HPLC system Varian ProStar (Varian Corp., USA, Model 410) was used.

Statistical analysis. Data were analyzed using one-way analysis of variance (ANOVA) with Statistica software package version 8.0 (StatSoft Inc., 2007). Means were compared with a PLSD Fisher's test. The differences between the control and experimental groups were considered to be statistically significant for $P<0.05$.

Results and discussion

By analyzing the pig production efficiency parameters (Table 2) were established, that the inclusion of 2.0 kg/t mixture of sodium butyrate and vegetable fatty acids in the feed the average body weight at 102, 135 and 156 days of age respectively increased by 6.00; 1.95 and 5.24 kg in comparison with the Control group, but the results were insignificant. The same tendency was observed by analysing results of an average daily gain and feed: gain ratio, when the sodium butyrate and vegetable fatty acids were added to the basal diet, but results were insignificant.

Table 2. **The influence of sodium butyrate and vegetable fatty acids on the weight of fattening pigs (kg)**

Items	**Control group**		**Experimental group**	
Age, days	**BW, kg**			
40	12.88 ±0.73		12.88 ±0.41	
74	33.94 ±0.98		32.75±0.86	
102	47.35 ±1.67		53.35 ±1.72	
135	81.01 ±3.06		82.96 ±2.48	
156	98.20 ±2.67		103.44 ±2.66	
Feeding period	**ADG**	**F:G**	**ADG**	**F:G**
I (40–74 days)	0.619 ±0.02	2.14 ±0.04	0.585±0.02	2.26 ±0.04
II (74–102 days)	0.487 ±0.04	3.88 ±0.84	0.736 ±0,05	2.43 ±0.11
III (102–135 days)	1.020±0.07	2.43 ±0.42	0.897 ±0.04	2.62 ±0.21
IV (135–156 days)	0.818 ±0.09	3.16 ±0.33	0.975 ±0.11	2.44 ±0.89
I- IV (40–156 days)	0.631±0.02	2.79 ±0.12	0.663±0.02	2.47 ±0.07

Table 3. **The influence of sodium butyrate and vegetable fatty acids on pigs' fattening muscularity (independent by pigs' sex)[1]**

Group	**Age in days**	**Weight, kg**	**Fat thickness, mm**		**Mouscles thickness, mm**	**Muscularity, %**
			1 point	2 point		
Control	156	98.81 ±2.50	13.44 ±0.45	12.75 ±0.39	55.69 ±1.91	58.49 ±0.32
Experimental	156	103.44±2.66	13.19 ±0.56	12.81 ±0.43	57.00 ±1.43	58.75 ±0.41

[1] From each group selected 8 pigs for fattening (for the measurement with „Piglog-105" pigs selected from 85-110 kg)

Our results are inconsistent with Le Gall M. et al. (2009), who found, that sodium butyrate possitive influenced to fattening pigs' body growth. In study of Le Gall M. et al. (2009) pig growth performance, feed intake and various end-point indices of gastrointestinal anatomy and physiology were investigated at slaughter. The pigs supplemented with sodium butyrate before weaning grew faster after weaning than the controls. The feed intake was

higher in pigs supplemented with sodium butyrate before or after weaning. In conclusion, the pre-weaning sodium butyrate supplementation was the most efficient to stimulate body growth and feed intake after weaning (Bedford et al., 2017).

By measuring the fattening pigs thickness of muscle (*M. longissimus dorsi*) and fat (Table 3) and calculating the muscularity, the results showed that the thickness of fat in the experimental group in 1st point was 2% thinner, in 2nd point identical to the control group, also pigs of experimental group had 2% thicker muscle than control group. The additive of sodium butyrate and vegetable fatty acids in the diet did not have a significant effect on muscle mass. Data are statistically unreliable (P>0.05).

Table 4. **The influence of sodium butyrate and vegetable fatty acids on physical properties of pigs *M. Longissimus dorsi***

Items		**Control group**	**Experimental group**
Color	L*	58.14 ±0.89	57.63±0.54
	a*	11.67±0.32	12.27±0.41
	b*	4.01±0.18	3.60±0.18
Drip loss, %		4.20±0.79	4.93±1.10
Water holding capacity, mg/%		58.36±0.98	55.96±1.00
Cooking loss, %		20.32±1.52	22.30±1.13
Tenderness, kg/cm^2		2.06±0.17	1.86±0.09

The evaluation of one of the most important characteristics of pork meat for consumers – its' physical properties. Meat colour depends on pH. After slaughter, muscle pH decreases because of the conversion of glycogen into lactic acid and it caused modification of the optical properties of meat, as it becomes opaque and clear solid red (Judge et al., 1989). Research showed that supplementation of sodium butyrate and vegetable fatty acids had effect on the meat colour: the redness (a*) of meat of the experimental group was 5% higher, while the yellowness (b*) - 10% lower than control group. The water content of fattening pigs' meat in experimental group was by 0.73% and cooking losses – by 1.98%, water holding capacity and tenderness – by 2.4% and 0.2% respectively, in comparison with the control group. Data is not statistically reliable.

Table 5. **The influence of sodium butyrate and vegetable fatty acids on pH of pigs *M. Longissimus dorsi***

Time, hours	**Group**	
	Control	**Experimental**
1	5.54 ± 0.05	5.52 ± 0.03
24	5.68 ± 0.06	5.67 ± 0.05
48	5.56 ± 0.02	5.63 ±0.03
72	5.58 ± 0.04	5.60 ± 0.03

Table 6. **The influence of sodium butyrate and vegetable fatty acids on pigs' meat chemical composition (%)**

Items	**Group**	
	Control	**Experimental**
Dry matter	29.06 ±0.73	28.86 ±0.90
Pure protein	23.73 ±0.76	22.59 ±0.56
Fat	4.39 ±1.15	5.27 ±1.37
Ash	0.86 ±0.09	0.90 ±0.09

Immediately after pigs slaughtering at 24, 48 and 72 hours was measured *M. longissimus dorsi* pH, which is contained in Table 5. pH values between control and the test do not differ significantly.

The influence of sodium butyrate and vegetable fatty acids on pigs' meat chemical composition submitted in Table 6. There were no differences in meat chemical composition between the groups in our study.

Table 7. **The influence of sodium butyrate and vegetable fatty acids on the accumulation of cholesterol in the meat of pigs for fattening**

Group	**Cholesterol, mg/100 g**
Control	30.80±1.89
Experimental	29.39±3.01

Cholesterol concentrations in *M. longissimus dorsi* of fattening pigs summarized in Table 7. Study showed that cholesterol in the *M. longissimus dorsi* was 5% lower in experimental group compared to the control group (P>0.05).

Cholesterol level in pork affects genetic variation, animal diet, fat thickness, type of cut, maturity and degree of marbling (Harris et al., 1993; Bragagnolo and Rodriguez-Amaya, 2002; Cannata et al., 2010).

Our study results shows that supplements used in this experiment can be used as growth promoters. When sodium butyrate was fed to piglets they grew faster than control groups. Lu et al. (2008) as in our study found out that piglet body weight gains grew proportionally to the butyrate doses. In following experiment comparative low dose of butyrate included (0.5–1.0 g per kg of feed), which is why we decided to use its higher amount. Other studies by Biagi et al. (2007) included sodium butyrate into the diets of 32-day-old piglets at 1, 2 or 3 g per kg of feed for 42 days. By growth performance, intestinal morphology, intestinal microbiota thoughout the trial did not show significant differences between treatments. Authors indicated that the lack of response in these

parameters might have been due to a different dietary composition or gut maturation status. Nevertheless, differences were observed in the cecum of sodium butyrate fed pigs, which increased cecal pH, concentrations of cecal chime ammonia and cecal isobutyric acid. These results suggest that sodium butyrate can influence the activity of the cecal microbiota and may present a possibility to deny the negative effects of early weaning through the manipulation of energy sources in the hindgut.

Conclusions

The inclusion on 2.0 kg/t sodium butyrate and vegetable fatty acids in the diets of fattening pigs increased the weight of pigs and increased daily gain by 5% and gain ratio by 12% and cholesterol levels by 5% compared to the control group, but there were no significantly different.

References

1. AOAC. Official methods of analysis. 15th ed. Association of official analytical chemists. Arlington, Virginia, USA. 1990.

2. Bedford A., Gong J., Implications of butyrate and its derivatives for gut health and animal production. Animal Nutrition. 2017. http://dx.doi.org/10.1016/j.aninu.2017.08.010

3. Biagi G., Piva A., Moschini M., Vezzali E., Roth F. X. Performance, intestinal microflora, and wall morphology of weanling pigs fed sodium butyrate. Journal of Animal Science. 2007. Vol.85. P. 1184–1191.

4. Bratzler L. J. Determining the tenderness of meat by use of the Warner-Bratzler method. Proc. Recip. Meat Conference. 1949. Vol. 2. P. 117–121.

5. Cannata S., Engle T. E., Moeller S. J., Zerby H. N., Radunz A. E., Green M. D., Bass P. D. Effect of visual marbling on sensory properties and quality traits of pork loin. Meat Science. 2010. Vol. 85, No 3. P. 428–434.

6. Grau R., Hamm R. Die Bestimmung des Wasserbindung des Fleisches mittels der Pressmethode. Fleischwirtschaft. 1956. Vol. 36. P. 733–736.

7. Henry R. W., Pickard D. W., Hughes P. E. Citric acid and fumaric acid as food additives for early-weaned piglets. Animal Production Science. 1985. Vol. 40. P. 505–509.

8. Harris K. B., Cross H. R., Pond W. G., Mersmann H. J. Effect of dietary fat and cholesterol level on tissue cholesterol concentrations of growing pigs selected for high or low serum cholesterol. Journal of Animal Science. 1993. Vol. 71. P. 807–810.

9. Le Gall M., Gallois M., Seve B., Louveau I., Hoist J. J. Comparative effect of orally administered sodium butyrate before or after wean¬ing on growth and several indices of gastrointestinal biol¬ogy of piglets. British Journal of Nutrition. 2009. T. 102. P. 1285–1296.

10. Lu J. J., Zou X. T., Wang Y. M. Effects of sodium butyrate on the growth performance, intestinal microflora and morphology of weanling pigs. Journal of Animal and Feed Sciences. 2008. Vol.17. P. 568–578.

11. Judge M. D., Aberle E. D., Forrest J. C., Hedrickand H. B., Merkel R. A. Principles of Meat Science. Kendall/Hunt Publishing Company, Dubuque. 1989.

12. Polak T., Rajar A., Gašperlin L., Žlender B. Cholesterol concentration and fatty acid profile of red deer meat. Meat Science. 2008. Vol. 80. P. 864–869.

13. Bragagnolo N., Rodriguez-Amaya D. B. Simultaneous determination of total lipids, cholesterol and fatty acids in meat and backfat of suckling and adults pigs. Food Chemistry. 2002. Vol. 79. P. 255–260.

14. NRC Nutrition Requirements of Swine. Washington, DC, USA: National Academy Press, 11. 2012.

15. PIGLOG 105 Users Guide. Soborg, Denmark: SFK – Technology. 1991.

16. Piva A., Morlacchini M., Casadei G., Gatta P. P., Biagi G., Prandini A. Sodium butyrate improves growth performance of weaned piglets during the first period after weaning. Italian Journal of Animal Science. 2002a. Vol. 1.P. 35–41.

17. Piva A., Prandini A., Fiorentini L., Morlacchini M., Galvano F., Luchansky J. B. Tributyrin and lactitol synergistically enhanced the trophic status of the intestinal mucosa and reduced histamine levels in the gut of nursery pigs. Journal of Animal Science. 2002b. Vol. 80. P. 670–680.

18. Thacker P. A. Alternatives to antibiotics as growth promoters for use in swine production: a review. Journal of Animal Science and Biotechnology. 2013. Vol. 4. P. 78.

19. Wiseman J., Garnsworthy P. C. The role of lipids in animal feeds. In: Gunstone, F.D., Padley, F.B. (Eds.), Lipid Technologies and Applications. 1997. Marcel Dekker, Inc., New York, USA.

Received 5 May 2018
Accepted 10 May 2018