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Influence of Chelators, Zn Sulphate and Silicic Acid on Productivity and Meat Quality of Fattening Pigs

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Abstract**—**The objective of this study was to investigate the influence of special additives such as chelators, zinc sulphate and silicic acid on productivity parameters, carcass characteristics and meat quality of fattening pigs. The test started with 40 days old fattening pigs (mongrel (mother) and Yorkshire (father)) and lasted up to 156 days of age. During the fattening period, 32 pigs were divided into 2 groups (control and experimental) with 4 replicates (total of 8 pens). The pigs were fed for 16 weeks' *ad libitum* with a standard wheat-barley-soybean meal compound (Control group) supplemented with chelators, zinc sulphate and silicic acid (dosage 2 kg/t of feed, Experimental group). Meat traits in live pigs were measured by ultrasonic equipment Piglog 105. The results obtained throughout the experimental period suggest that supplementation of chelators, zinc sulphate and silicic acid tend to positively affect average daily gain and feed conversion ratio of pigs for fattening ($p < 0.05$). Pigs' evaluation with Piglog 105 showed that thickness of fat in the first and second point was by 4% and 3% respectively higher in comparison to the control group ($p < 0.05$). Carcass weight, yield, and length, also thickness of fat showed no significant difference among the groups. The water holding capacity of meat in Experimental group was lower by 5.28%, and tenderness – lower by 12% compared with that of the pigs in the Control group ($p < 0.05$). Regarding pigs' meat chemical composition of the experimental group, a statistically significant difference comparing with the data of the control group was not determined. Cholesterol concentration in muscles of pigs fed diets supplemented with chelators, zinc sulphate and silicic acid was lower by 7.93 mg/100 g of muscle in comparison to that of the control group. These results suggest that supplementation of chelators, zinc sulphate and silicic acid in the feed for fattening pigs had significant effect on pigs growing performance and meat quality.

Keywords**—**Chelators, meat quality, pigs, silicic acid, zinc sulphate.

I. Introduction

THE livestock and meat industries are constantly seeking alternatives to promote growth performance and improve carcass characteristics [1].

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It is generally known that pork meat is food with relevant nutritional features because it is rich in high biological value proteins, many vitamins, minerals especially heme iron, trace elements, and other bioactive compounds [2]. However, pork meat also contributes to the intake of fat, especially of saturated fatty acids, cholesterol, and other matterials that, inadequate amounts, may result in negative physiologically and nutritional effects [3], [4].

The genetic improvement of production traits such as growth rate, lean content, backfat thickness, and feed efficiency was the main factor of selection strategies in pigs sector [5]-[7]. Meat quality is a complex traits that range from technological to meat-eating quality parameters (subjective). Technological aspects of meat quality involve such properties as homogeneity and intensity of colour, firmness, shelf-life, water holding capacity, cooking loss and various processing yields [8], [9]. Product colour, leanness, amount of fat tissue and water holding capacity are traits associated with appearance that influences consumer satisfaction with the product. [10].

The improvement of meat quality became one of the main tasks and gained considerable attention in recent years. Studies have shown that some feed additives, such as vitamins, minerals, antioxidants and etc., can improve nutritional and sensory characteristics of pork [11], [12].

Since the use of antibiotics as growth promoters has been complete banned and the requirements on pork producers for the increasing quality of meat are rising, this situation is favourable for the intensification of studies for the usage of feed additives [13].

In order to improve pork production and its quality, many attempts have been made. Since pigs are monogastric species, feed additives in diets could have direct effect on pigs performance and thus on meat quality [14]-[16].

The meat industry should consistently produce and supply tasty, safe and healthy, i.e. high quality meat, because it has always been essential to the consumers. In order to produce such meat, it is necessary to understand the characteristics of meat quality traits and factors to control them.

The quality of fresh meat is difficult to characterize because it is a complex concept determined by acceptability for consumers. Since fresh meat is animal tissue and is applicable for use as food, various factors can influence its quality characteristics. These are composition of the diet, environment, stress and pre-slaughter effects, post-mortem changes in muscle tissues, muscle structure, chemical composition of meat, product handling, processing and storage, microbiological numbers and populations, etc. [17].

Organic acids are wildly distributed in nature as constitutes of plants or animals. Organic acids have the ability to acidify feed and digesta and can inhibit the growth of microbes, so they have been used for decades in commercial diets as effective preservatives of feedstuff [18]. Organic acids have interest as an alternative additive in pigs nutrition and relevant research confirms positive effects on growth performance in all classes of pigs [19]-[21]. Organic acids and their salts can lower the gastric pH, resulting in an increased gastric emptying (gastric retention) and improved activity of proteolytic enzymes. Organic acids have shown to modify bacterial populations in the gastro-intestinal tract of pigs [22], [23].

Acidifying products used in pig diets can be organic or inorganic acids and their salts. The following acidifiers are officially approved in the EU: Na-sorbate, Ca-sorbate, K-sorbate, tartaric acid, Na-tartarate, K-tartarate, NaK-tartarate, NH_3-formate, Na-formate, NH_3-propionate, Na-propionate, K-acetate, Ca-acetate, Na-diacetate, Na-citrate, K-citrate, K-lactate, benzoic acid and Na-benzoate. These acidifiers can be administered individually or as a mix in the feed or the drinking water [24].

The investigations, have been carried out so far, revealed the necessity to focus greatest attention to the solution of problems related to animals' intestinal health, optimization of digestive processes resulting in improved performance and enhanced quality of animal production.

Usage of chelators, zinc sulphate and cilicic acid oils in pig nutrition for meat quality comprises the new trend for investigation. So, the aim of this study was to determine the effect of chelators, zinc sulphate and cilicic acid on productivity, carcass traits and meat quality of pigs for fattening.

II. Materials and Methods

A. Experimental Design and Animals Keeping and Feeding

The trial with pigs for fattening were conducted following the regulations of the Republic of Lithuania for animal welfare and handling and in accordance with EU Directive 2010/63/EEC and the EC recommendation 2007/526EC 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 performed with 40-day old (mongrel (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. The pigs of Control group were fed *ad libitum* with a standard wheat-barley-soybean meal compound diet and the Experimental group diets was the same as in the Control group, but were supplemented with chelators, zinc sulphate and silicic acid (dosage 2 kg/t of feed). The diet was formulated to meet the nutrient and energy requirements for pigs for fattening [25]. 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 conversion ratio 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).

B. Characteristics of Preparations Used in the Study

The additives mixture used in the experimental diets consists of esterified butyrins (3.00%), ammonium propionate (2.80%, E284), chelators (15.00%), mixture of flavouring substances (0.80%), zinc sulphate monohydrate (2.50%, 35% Zn), precipitated and dried silicic acid (5.00%, E551a) and carrier (70.90%).

C. The Assessment of Carcass Traits

Before pigs' slaughter fat thickness at the waist area was measured at 3-4 vertebras of loin and 7 cm towards underbelly from middle back line (FAT-1), and 10 cm from the last vertebra to the cranial side (FAT-2). In this point was also measured thickness of *M. longissimus dorsi* (mm). These measurements were made with ultrasound equipment „Piglog-105" (SFK Technology, 1991) [26].

At the end of the trial (156 days) eight fattening pigs from each group (i.e. total 16 pigs) were selected and slaughtered according to standard procedures.

Left carcass halve was taken for the assessment of carcass traits, cooled for 24 hours at 0±4 °C and then determined:

- Carcass weight (kg);
- Cross-section of long dorsal muscle ("muscular eye"), meat and fat area in cm² (measured in section between the first and second lumbar vertebrae);
- Carcass yield in per cent (carcass weight ratio of pre-slaughter weight);
- Carcass part length, cm (measured from the front edge of first cervical vertebra to the front edge of the pubic bone);
- Bacon halves length, cm (measured from the front edge of first thoracic vertebra and to the front edge of the pubic bone);
- Ham weight, kg (fixed cut the carcass of a half at the penultimate and last lumbar vertebrae and then ham weighed);
- Back fat thickness, mm (measured the thickest point at 6-7 thoracic vertebra, at the10th rib, at the last rib and the lumbar area-its thinnest point and cross bone in the area in three places-against his thigh muscle surface above the muscle and the muscle). Back fat thickness measured with the skin.

D. The Evaluation of Physical and Chemical Properties of Meat and Cholesterol Content

The meat samples for the analysis of physical and chemical parameters and cholesterol content were taken from the M. longissimus dorsi between 12 and last rib. For samples, 500-550 g size of muscle was taken. The meat quality was evaluated 48 hours after slaughtering.

Physical characteristics: Meat colour was determined 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 physico-chemical properties of muscles such as cooking losses (the change in weight of the meat samples before and after cooking in a circulating bath at 70 °C), water-holding capacity (Grau and Hamm method), drip loss (the percentage of weight lost of the meat sample keeping for 24 hours at +4°C in special reticulate bags) and meat tenderness (Warner Bratzler test) were analysed.

M. longissimus dorsi pH at 1, 24, 48 and 72 hours *post-mortem* was measured using pH-meter "Inolab 730". Chemical composition of breast meat was determined by standard methods [27]. Cholesterol content was determined by HPLC system (Varian Inc., USA).

E. Statistical Analysis

The results of the experiment were analyzed using the 1-way ANOVA test, and significant differences between groups were determined by Duncan's multiple range test. Statistica 8.0 for Windows TM software was used. Differences were considered significant at P<0.05.

III. Results

A. Performance of Pigs Fed Chelators, Zn Sulphate and Silicic Acid Supplemented Diets

The effects of dietary treatments (chelators, Zn sulphate and silicic acid) on pigs' growth performance are presented in Table I. The test was started with an equal weight of fattening pigs. During all experimental period, supplements used in the diets had positive tendency on the weight of pigs, but the differences between the groups were not statistically significant. By analysing the results of average daily gain can be noticed, that it was higher for Experimental *versus* Control group in each feeding periods, but the statistical differences between groups were observed only during all study period (40–156 days in age) – 0.654 *vs.* 0.631 kg or it was by 4% higher (P<0.05).

The effect of the supplements in the pigs' diets for the feed conversion ratio was observed at the IV feeding period – in Experimental group it was lower than in the Control group (2.42 *vs* 3.16). During all study period (40-156 days) feed conversion ratio of fattening pigs, fed diet supplemented with chelators, Zn sulphate and silicic acid was by 10% lower compared to Control group.

B. Evaluation of Pigs Fed Diets Supplemented with Chelators, Zn Sulphate and Silicic Acid Carcass Traits and Physical Properties

By measuring the muscle (*M. longissimus dorsi*) and fat thickness of fattening pigs' and by calculating the percentage of muscularity (Table II), it can be concluded that the differences between Experimental and Control groups were not observed. However, fat thickness of the 1st and 2nd point of the *M. longissimus dorsi* was by 4% and 3% higher (P<0.05) for treated and control animals respectively.

The effect of chelators, Zn sulphate and silicic acid on pigs' carcass traits is presented in Table III. All the investigated parameters did not show statistically significant difference among the groups (P>0.05).

TABLE I
Growth Performance of Fattening Pigs Fed Diets with Chelators, Zn Sulphate and Silicic Acid (kg)

Items	Control group		Experimental group	
BW (initial)	12.88 ± 0.73		12.81 ± 0.77	
BW (final)	98.20 ± 2.67		102.00 ± 2.84	
Periods	**ADG**	**F:G**	**ADG**	**F:G**
I feeding period (40 – 74days)	0.619	2.14	0.616	2.15
II feeding period (74 – 102 days)	0.487	3.88	0.560	3.19
III feeding period (102 – 135 days)	1.020	2.43	0.967	2.43
IV feeding period (135 – 156 days)	0.818	3.16^a	0.984	2.42^b
All periods (40 – 156 days)	0.631^a	2.79^a	0.654^b	2.50^b

$^{a,\ b}$ – means within each row with different superscripts are significantly different at P < 0.05.

TABLE II
The Influence of Chelators, Zn Sulphate and Silicic Acid on Muscularity of Pigs for Fattening (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	$13.44±0.45^a$	$12.75±0.95^a$	55.69±1.91	58.49±0.32
Experimental	156	101.13±3.17	$14.00±0.61^b$	$13.13±0.69^b$	56.07±2.31	58.56±0.62

$^{a,\ b}$ – means within each column with different superscripts are significantly different at P < 0.05.
[1] From each group selected 8 pigs for fattening (for the measurement with "Piglog-105" is selected pigs from 85-110 kg).

The evaluation of one of the most important characteristics of pork meat for consumers – its' physical properties showed, that supplementation of chelators, Zn sulphate and silicic acid had effect on the meat colour: the redness (a*) of meat of the Experimental group was 5 % higher, while the yellowness (b*) - 5 % lower than in the Control group. Analysis of the effect of feed supplementation on the other physical properties of meat showed that it had effect on the water holding capacity and tenderness, which were by 5.28% and 11.60 %, respectively, lower (P<0.05) than in the Control group of pigs (Table IV).

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

TABLE III
THE INFLUENCE OF CHELATORS, ZN SULPHATE AND SILICIC ACID ON ASSESSMENT INDICATORS OF PIGS' CARCASS TRAITS

Characteristics		Group	
		Control	Experimental
Live weight, kg		99.80±1.08	97.20±1.47
Carcass weight, kg		65.52±2.60	62.56±2.09
Carcass yield, %		65.63±2.37	64.32±1.45
M. longissimus dorsi area, cm^2		48.88±0.84	43.54±1.20
Carcass part length, cm		95.60±1.48	96.40±1.35
Bacon halves length, cm		78.80±1.08	80.00±0.94
Ham weight, kg		12.31±0.26	11.94±0.35
Thickness of fat, mm	at 6-7 thoracic vertebrae	19.60±1.44	18.20±3.03
	at the 10^{th} rib	17.20±1.08	16.60±2.95
	at the last rib	16.20±1.24	16.40±2.49
	its thinnest point	16.00±0.71	13.20±3.60

TABLE IV
INFLUENCE OF CHELATORS, ZN SULPHATE AND SILICIC ACID ON PHYSICAL PROPERTIES OF PIGS *M. LONGISSIMUS DORSI*

Items		Group	
		Control	Experimental
Color	L*	58.14±0.89	58.73±0.96
	a*	$11.67±0.32^a$	$12.26±0.75^b$
	b*	$4.01±0.18^a$	$3.81±0.28^b$
Drip loss, %		4.20±0.79	5.47±0.52
Water holding capacity, mg/%		$58.36±0.98^a$	$53.08±1.73^b$
Cooking loss, %		20.32±1.52	20.17±1.74
Tenderness, kg/cm^2		$2.06±0.17^a$	$1.82±0.16^b$

$^{a,\,b}$ – means within each rows with different superscripts are significantly different at P < 0.05.

TABLE V
INFLUENCE OF CHELATORS, ZN SULPHATE AND SILICIC ACID ON PH OF PIGS *M. LONGISSIMUS DORSI*

Time, hours	Control group	Experimental group
1	5.54 ± 0.05	5.57 ± 0.04
24	5.68 ± 0.06	5.64 ± 0.04
48	5.56 ± 0.02	5.60 ± 0.03
72	5.58 ± 0.04	5.60 ± 0.05

TABLE VI
THE INFLUENCE OF CHELATORS, ZN SULPHATE AND SILICIC ACID ON CHEMICAL PROPERTIES OF PIGS *M. LONGISSIMUS DORSI*, %

Items	Group	
	Control	Experimental
Dry matter	29.04±0.81	33.10±1.42
Protein	21.26±1.57	22.39±0.99
Fat	6.51±0.86	9.47±1.67
Ash	1.27±0.07	1.23±0.03

C. Evaluation of Chelators, Zn Sulphate and Silicic Acid on Chemical Properties of Meat

The effect of chelators, Zn sulphate and silicic acid on chemical properties of pigs *M. longissimus dorsi* were presented in the Table VI. According to the present result, none of the analysed chemical parameter of meat differ among the treatments.

The total cholesterol content in the *M. longissimus dorsi* of pigs for fattening, fed diets with chelators, Zn sulphate and silicic acid supplementation is presented in Table VII. The cholesterol content in the Experimental group was by 26% lower (*P*<0.05) in comparison to the Control group.

TABLE VII
INFLUENCE OF CHELATORS, ZN SULPHATE AND SILICIC ACID ON TOTAL CHOLESTEROL CONTENT OF PIGS *M. LONGISSIMUS DORSI*, MG/100 G

Group	Cholesterol
Control	$30.80±1.89^a$
Experimental	$22.87±2.39^b$

$^{a,\,b}$ – means within each column with different superscripts are significantly different at P < 0.05;

IV. DISCUSSION

Production data over the BW range 13 to 102 kg showed that pigs fed diets with complex of organic acids, chelators, Zn sulphate and silicic acid had no influence on the weight of pigs for fattening. However other productivity parameters, t. i. weight gain and feed conversion ratio during all experimental period were improved when the complex of preparations was included. These data do not allow to ascertain the reason(s) for this improvement, but it could be attributable to an improved nutrient digestibility Additionally Zn is involved as co-factor in myriad of metabolic enzyme systems within the pig, and their greater availability over the entire study could have caused the improvement in FCR. Further experimentation is required to confirm this finding. In addition, [28] studied the effect of organic acids as a feed complement on FCR and found that it improved by 4.2% compared to pigs without supplemented acids. The daily live weight gain was improved by 5.8%. When acetic acid has been supplemented to the diet it has not resulted in either an increased average daily gain or FCR [29], [30].

Reference [31] showed that the addition of butyrate into pigs' diets had no effect on productivity compared with the control group. No significant difference in carcass weight or carcass lean percentage was determined between the treatments. Also organic acids showed to tense an antimicrobial effect in the digestive tract of pigs [32]-[34]. The lack of effect on productivity can be due to minor antimicrobial effect of butyrate supplemented diets in the small intestine [31]. Meanwhile, fat coated Ca-butyrate improved digestive and absorptive capacities in the small intestine of pigs [35]. The addition of organic acid in the diets did not affect carcass quality of male pigs.

The evaluation of pork meat physical properties in present study showed, that supplementation of chelators, Zn sulphate and silicic acid had effect on the meat colour. The meat became more redness. The meat colour is very important for consumers. Preferably fresh pork colour should be reddish-pink. The dark, pale or similar colours in meat are not desirable for the consumer's.

Meat colour depends on pH, after slaughter, muscle pH decreases as a result of the conversion of glycogen into lactic acid and this causes modification of the optical properties of meat as it becomes opaque and clear solid red [36]. Abnormal colour conditions such as PSE (pale, soft and exudative) and DFD (dark, firm and dry) can appear [37] when meat reaches a pH of 5.5 at 40 min p.m. or a pH of 6.8 at 24 h p.m, respectively. In the present study pH values of the *M. longissimus dorsi* of the Experimental group was 5.57 at 1 h p.m, and 5.60 at 72 h p.m. and the differences between treatments were not detected. By analysing the effect of feed supplementation on the other physical properties of meat were observed, that it had effect on the water holding capacity and tenderness. It could be releated also with pH. The rate of pH change after slaughter is one of the most important factors influencing meat quality. Irregular rate of decline in pH is associated with such distinct abnormalities: pale, soft, exudative (PSE); dark, firm, dry (DFD) and acid meat [9], [38]. Low pH is also associated with low water holding capacity and high drip loss [8], [10]. Final pH also affects parameters such as tenderness, juiciness, and taste.

If water holding capacity is low, water loss during storage is increased as a result of surface evaporation or exudation from meat as drip loss [36]. A rapid p.m. drop in pH accelerates rigor mortis, thus decreasing water holding capacity and producing greater amounts of exudate [39]. An inverse relationship exists between DL and pH, so when pH is low, drip loss is high.

According to the present result, no one of the analysed chemical parameter of meat differ among the treatments. These results are in contradictory of reference [40], who reported that supplementation of zinc in the ration of pigs improved chemical composition (total protein and total water content) of pork meat. Cholesterol in pork is influenced by genetic variation, animal diet, fat thickness, type of cut, maturity and degree of marbling [41]-[49]. The genetic and environmental factors, and nutrition influences the cholesterol content in the body [50]. In the present study, a positive tendency to lower cholesterol content in the *M. longissimus dorsi* was observed in the experimental group vs. Control group (30.80 mg/100 g vs. 22.87 mg/100 g; P<0.05). According to reference [51], [52] cholesterol content of m. longissimus dorsi of pigs ranges from 58 to 73 mg/100 g fresh tissue. Reference [44] determined, that cholesterol content of pork is from 30 to 81 mg/100 g for raw pork.

V. Conclusion

The results of this experiment indicate that feed additive consisting of chelators, zinc sulphate and silicic acid improved pigs growth performance characteristics such as ADG and F:G ratio, but did not influence carcass characteristics, meat pH after 1, 24, 48 and 72 h p. m, or chemical composition of *M. longissimus dorsi.* However, the supplementation of chelators, zinc sulphate and silicic acid in the feed for fattening pigs, decreased water holding capacity and tenderness of meat. Cholesterol content in the muscles of pigs fed diets supplemented with chelators, zinc sulphate and cilicic acid was lower by 26% (P < 0.05) in comparison to the group without additives.

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