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EFFECT OF INULIN AND GARLIC SUPPLEMENTATION IN PIG DIETS

Eugeniusz R. Grela[1], Krzysztof Pietrzak[1], Sandra Sobolewska[1], Piotr Witkowski[2]

[1]Institute of Animal Nutrition and Bromatology, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland
[2]Wrębiak-Witkowski Meat Processing Plant Ltd., Zamojska 46, 22-600 Tomaszów Lubelski, Poland
Corresponding author: ergrela@interia.pl

Abstract

The aim of the study was to determine the effect of supplementing inulin and inulin with garlic extract to pig diets on performance, carcass traits, blood metabolic profile and fatty acid composition of *longissimus* muscle. The experiment was carried out on 48 crossbred [(PL × PLW) × Duroc] fattening pigs with an initial body weight of 30.0 ± 0.5 kg, which were allocated to 3 groups: I (control), II (3% inulin) and III (3% inulin + 500 ml garlic extract added to 1000 l of drinking water). The pigs whose diets were supplemented with inulin or inulin and garlic achieved significantly (P≤0.05) higher daily weight gains compared to control. Supplemental inulin and water extract of garlic significantly (P≤0.05) lowered cholesterol content in blood and *longissimus* muscle. The highest level of omega-3 and omega-6 fatty acids was established in the *longissimus* muscle from pigs in group III.

Key words: pig, inulin, garlic, blood, fatty acids

Implementation of the ban on antibiotic growth promoters in animal feeds has prompted the search and more intensive studies on the application of alternative biologically active substances that improve the overall efficiency of animals and, importantly, are safe for humans, animals and the environment (Windisch et al., 2008). The alternative growth promoters including herbs, prebiotics and/or eubiotics deserve special attention (Grela et al., 2011).

Extensive research has been carried out on the use of fresh, dried or lyophilized forms of garlic (*Allium sativum* L.) and its preparations as essential oils or water extracts for supplementation of animal diets (Holden and McKean, 2000; Grela and Klebaniuk, 2007; Yan et al., 2011). Garlic contains active substances such as alliin, which is converted into another compound allicin, that have strong bactericidal and bacteriostatic properties and are very effective against some strains of bacterial pathogens in the digestive system (Amagase et al., 2001; Tatara et al., 2005). Whereas other compounds from the cysteine derived group, i.e. S-allyl cysteine (SAC), S-ethyl cysteine (SEC) and S-propyl cysteine (SPC) are likely to enhance the immunomodulatory and immune changes in the body (Kandil et al., 1987; Isaacsohn et al., 1998). Garlic additives lower cholesterol content in hepatocytes (Konjufca et al., 1997), reduce formation and secretion of VLDL proteins as well as inducing health-promoting changes in the dietary fatty acid profile in humans (Yan et al., 1992).

A positive impact of the prebiotic inulin on monogastric animals was indicated by some authors (Loh et al., 2006; Kjos et al., 2010) who highlighted the stimulation of *Bifidobacteria* and *Lactobacillus* development, limitation of enterobacteria population growth, beneficial influence on the intestinal immune system and modulation of lipid metabolism (Crittenden and Planyne, 1996). These feed additives affect gastrointestinal flora and the body metabolism and thus can improve productive performance of animals, their body condition as well as modifying blood metabolic profile.

The objective of the present study was to assess the effect of inulin or inulin and garlic water extract inclusion in pig diets on overall efficiency and carcass quality, some parameters of blood metabolic profile and fatty acid composition in *longissimus* muscle.

Material and methods

The experiment was carried out on 48 crossbred [(PL × PLW) × Duroc] growing pigs with an initial body weight of 30.0±0.5 kg, which were allocated to 3 equal groups (Table 1) and kept in a group of 4 animals per pen. The fattening pigs were fed standard grower (30–70 kg) and finisher diets (71–110 kg). The diets comprised ground grain (wheat and barley), soybean meal, soybean oil and mineral feeds (salt, monocalcium phosphate and ground limestone), and standard mineral-vitamin premix for pigs. The feeds were balanced for metabolizable energy, protein, amino acids, minerals and vitamins (Grela et al., 2009). In groups II and III, wheat starch was replaced with inulin extracted from chicory roots (Orafti HPX, 100% inulin). Group III received extra 500 ml of water garlic extract added to 1000 l of drinking water. The garlic preparation was standardized for allicin content (5000 mg in 1 l). The animals had free access to feeders that allowed *ad libitum* consumption and to drinkers. The hygienic conditions, that is temperature, relative humidity and cooling were the same in all the groups. The content of basic feed nutrients was determined with standard methods (AOAC, 2005) and metabolizable energy was calculated according to the equation of Kirchgessner and Roth (1983).

Table 1. Experimental design

Trait	Groups		
	I control	II inulin	III inulin and garlic
Inulin additive (g kg^{-1} feed)	0	30	30
Aqueous extract of garlic (ml 1000 l^{-1} water)	0	0	500

Blood for analyses was collected three times from the jugular vein of 8 pigs at about 40, 70 and 100 kg body weight. Blood serum was obtained by centrifugation of whole blood at 3000 rpm for 10 min. at 4°C. Blood serum was used to assay the level of lipid metabolism parameters: triacylglycerol, total cholesterol and HDL (high-density lipoprotein) cholesterol fraction. The level of LDL (low-density lipoprotein) cholesterol was estimated by the formula of Friedewald et al. (1972). These parameters were analysed in the blood serum with colorimetric methods using Biomaxima monotests, a Metrolab biochemistry analyser and a Cary 50 spectrophotometer.

The pigs were slaughtered at about 110 kg body weight. Carcasses were assessed according to the SKURTCh (Pig Testing Station) methods (Różycki and Tyra, 2010). The samples of *longissimus* muscle for analyses were collected between the last thoracic and the first lumbar vertebra. Fat extraction process from muscle tissue was carried out by the method of Folch et al. (1957), after which fat was examined for cholesterol content according to Rhee et al. (1982) procedure, whereas fatty acid profile was evaluated with gas chromatography on a Varian CP-3800. The operating conditions for chromatographic separation were as follows: capillary column CP WAX 52CB 0.25 mm × 60 m, carrier gas – helium, flow rate 1.4 ml min^{-1}, column temperature 120ºC gradually increasing by 2ºC min^{-1} up to 210ºC, determination time – 127 min, feeder temperature – 160ºC, detector temperature – 160ºC, other gases – hydrogen and oxygen.

The results were subjected to analysis of variance (ANOVA) to provide mean values for the groups and standard error of the mean, while significance of differences for the mean values of the studied traits was determined with Duncan's test using Statistica package.

Results

The crude protein and metabolizable energy content of pig feeds in the growing and finishing periods (Table 2) was close to that calculated before the experiment began. Productive performance parameters for fattening pigs fed the inulin- and garlic-supplemented diet are summarized in Table 3. It is worth noting the reduced time of pig fattening when either inulin or inulin with garlic water extract were added. There were observed significantly higher ($P \leq 0.05$) daily weight gains throughout the fattening period in animals from groups II and III. Markedly better results were found in group III during the first stage of fattening and in groups II and III (supplemented with inulin and inulin with garlic extract, respectively) during the final stage. The maximum efficiency of feed conversion was established in group III and the differences between the groups were confirmed statistically.

In each group, the values of the analysed biochemical parameters (Table 4) fell within the normal reference range (Kuleta et al., 1993; Friendship and Henry, 1996; Winnicka, 2004). The blood lipid profile of pigs was modified as a result of the diet supplementation. Significantly ($P \leq 0.05$) lower LDL cholesterol levels compared to control were found in the blood serum of animals receiving the inulin and garlic additive. The dietary inclusion of inulin alone (group II) only tended to reduce total cholesterol compared to the control; however, the differences were not significant. In animals from group III, the HDL fraction (55.98%) was significantly higher than in the other groups. Likewise, the pigs receiving 3% dietary inulin (group II) had higher HDL cholesterol (49.07%) compared to group I (35.74 %).

Table 2. Nutritional value of the diets

Item	I Control	II Inulin	III Inulin + garlic
Grower			
Dry matter	876.3	877.1	877.2
Crude protein	180.3	179.8	179.6
Ether extract (g)	24.3	24.2	24.2
Crude fibre (g)	37.8	37.4	37.5
Crude ash (g)	43.8	43.7	43.7
N-free extract (g)	590.1	592.0	592.2
Metabolizable energy (MJ)	12.52	12.51	12.51
Finisher			
Dry matter	887.1	885.9	886.2
Crude protein	161.3	162.4	161.2
Ether extract (g)	24.9	24.8	24.8
Crude fibre (g)	39.3	39.1	39.2
Crude ash (g)	40.3	40.2	40.2
N-free extract (g)	621.3	619.4	620.8
Metabolizable energy (MJ)	12.93	12.91	12.91

Table 3. Fattening days, daily gains, feed intake and FCR

Item	Fattening period	Groups			P value	SEM
		I	II	III		
Fattening days	Grower	53 A	51 A	47 B	0.008	0.15
	Finisher	52 a	46 b	48 ab	0.033	0.26
	$\bar{x}$	105 a	97 b	95 b	0.019	0.14
Average daily gains (g)	Grower	763 A	774 A	862 B	0.007	5.52
	Finisher	781 a	885 c	858 b	0.039	5.67
	$\bar{x}$	772 a	826 b	860 c	0.021	4.47
Feed intake (kg)	Grower	2.22 a	2.41 b	2.31 ab	0.041	0.02
	Finisher	3.02 a	3.31 b	3.05 a	0.033	0.04
	$\bar{x}$	2.62 a	2.86 b	2.68 a	0.045	0.03
Feed conversion ratio (kg kg^{-1})	Grower	2.91 b	3.11 c	2.68 a	0.038	0.05
	Finisher	3.87 c	3.74 b	3.55 a	0.043	0.08
	$\bar{x}$	3.39 b	3.46 b	3.12 a	0.037	0.05

a, b, c – mean values in rows with different letters differ significantly (P≤0.05).
A, B – mean values in rows with different letters differ significantly (P≤0.01).

Fattening pigs from each group were slaughtered at 110±1.5 kg body weight (Table 5). Significantly higher indices of carcass meatiness, including ham percentage and loin eye area were determined in group III, in which pigs received the inulin and garlic extract additive in drinking water. Animals in this group also showed lowest backfat thickness (P≤0.05) and liver weight that was about 34% higher compared to groups I and II.

Table 4. Triacylglycerol and cholesterol content in blood plasma

Item	BW (kg)	Groups			P value	SEM
		I	II	III		
Total cholesterol (mmol l^{-1})	40	2.25 b	2.18 ab	2.03 a	0.039	0.034
	70	2.09	2.07	2.01	0.174	0.037
	100	2.13	2.09	2.11	0.269	0.033
	$\bar{x}$	2.17 b	2.11 ab	2.05 a	0.046	0.032
Triacylglycerols (mmol l^{-1})	40	0.22	0.26	0.21	0.138	0.010
	70	0.34 b	0.28 ab	0.25 a	0.031	0.012
	100	0.35 a	0.29 ab	0.27 a	0.043	0.010
	$\bar{x}$	0.30	0.28	0.24	0.058	0.011
HDL cholesterol (mmol l^{-1})	40	0.83 a	1.08 b	1.11 b	0.011	0.026
	70	0.76 a	1.03 b	1.02 b	0.012	0.039
	100	0.72 A	1.01 B	1.06 B	0.010	0.037
	$\bar{x}$	0.77 a	1.04 b	1.06 b	0.011	0.029
LDL cholesterol (mmol l^{-1})	40	1.33 C	0.99 B	0.82 A	0.009	0.032
	70	1.17 b	0.91 a	0.88 a	0.012	0.039
	100	1.25 B	0.95 A	0.93 A	0.007	0.037
	$\bar{x}$	1.25 B	0.95 A	0.88 A	0.004	0.035
% HDL cholesterol	40	36.87 a	49.41 b	54.95 c	0.013	5.234
	70	36.47 A	49.70 B	50.74 B	0.006	5.602
	100	33.87 A	48.09 B	50.25 B	0.004	5.857
	$\bar{x}$	35.74 A	49.07 B	51.98 B	0.004	4.985
Total/HDL cholesterol	40	2.71 c	2.02 b	1.82 a	0.012	0.108
	70	2.74 B	2.01 A	1.97 A	0.004	0.125
	100	2.95 B	2.08 A	1.99 A	0.003	0.127
	$\bar{x}$	2.80 B	2.04 A	1.93 A	0.003	0.132

a, b, c – mean values in rows with different letters differ significantly ($P \leq 0.05$).
A, B, C – mean values in rows with different letters differ significantly ($P \leq 0.01$).

Table 5. Carcass quality traits

Item	Groups			P value	SEM
	I	II	III		
Body weight at slaughter (kg)	110.6	110.7	111.2	0.367	0.142
Cold dressing yield (%)	77.6	77.1	77.2	0.538	0.036
Meat of ham (%)	79.9 a	80.3 a	81.4 b	0.046	0.121
Loin eye area (cm^2)	55.6 a	56.2 ab	58.9 b	0.032	0.167
Meatiness of carcass (%)	52.4 a	52.3 a	54.6 b	0.033	0.183
Backfat thickness:					
– shoulder (mm)	34.3 b	32.8 ab	29.8 a	0.043	0.218
– midback (mm)	23.0 b	21.8 ab	19.7 a	0.027	0.211
– rump (3 measurements) (mm)	15.3	15.4	14.9	0.121	0.072
– average from 5 measurements (mm)	20.6 b	20.2 b	18.8 a	0.027	0.213
Weight of liver (kg)	1.48 a	1.49 a	1.99 b	0.043	0.024

a, b, c – mean values in rows with different letters differ significantly ($P \leq 0.05$).

Table 6. Fatty acid composition (% of total FA) and cholesterol content (mg g^{-1}) in *longissimus* muscle

Fatty acids (%)	Groups			P value	SEM
	I	II	III		
∑ SFA	42.12 b	41.39 ab	39.83 a	0.042	0.41
∑ MUFA	54.77 a	55.48 ab	56.32 b	0.043	0.52
∑ PUFA	2.84 a	2.91 a	3.46 b	0.034	0.11
∑ PUFA omega-3	0.22 a	0.25 ab	0.39 b	0.031	0.07
∑ PUFA omega-6	2.47 a	2.63 ab	3.01 b	0.027	0.15
Total cholesterol (mg g^{-1} tissue)	64.5 b	63.6 b	58.9 a	0.038	0.92

a, b – mean values in rows with different letters differ significantly ($P \leq 0.05$).

Table 6 presents the fatty acid profile and cholesterol content in the *longissimus* muscle. Group III was found to demonstrate a significantly ($P \leq 0.05$) lower percentage of saturated fatty acids and higher percentage of unsaturated acids, especially omega-3 and omega-6 as against the control. Importantly, fat from the *longissimus* muscle obtained from this group had a notably reduced cholesterol content.

Discussion

Numerous Polish and foreign studies address the problem of beneficial impact of garlic or inulin incorporation into fattener diets. The effectiveness of these dietary supplements depends on dose size and form as well as their source. A study by Kjos et al. (2009) on pigs clearly shows that the effect of polysaccharide additive varies according to the dose. Weight gains in the first and second stage of fattening were found to increase noticeably along with dietary inulin increasing from 3% to 6%. Other studies highlight a positive impact of garlic on productive performance (Grela and Klebaniuk, 2007; Yan et al., 2011). The beneficial impact is attributed to bacteriostatic compounds of garlic, mainly allicin and cysteine derivatives (Kandil et al., 1987; Isaacsohn et al., 1998; Amagase et al., 2001). The noteworthy performance results obtained in the present study in group III support the appropriateness of the combined application of inulin and garlic as an eubiotic (Grela et al., 2011). The combined use of inulin and garlic extract (group III) in the finisher period decreased weight gains of pigs compared to those receiving inulin alone. Therefore it seems that the garlic extract additive can be recommended mainly in the growing fattening period.

Physiologically relevant hematological parameters are important markers of animal health and homeostasis. Supplementation of the diet with 3% inulin contributed to increased HDL cholesterol in the blood serum of fatteners. However, Pedersen et al. (1997) did not find any considerable effect of inulin addition on the discussed blood parameters. Meanwhile, Yasuda et al. (2006) reported that growing pigs responded positively to a 4% inulin supplement with elevated hemoglobin levels. A number of authors (Qureshi et al., 1987; Yeh and Yeh, 1994; Yeh and Liu, 2001; Durak et al., 2004) have stressed the important and well-proven health benefits of garlic, e.g. its antiatherosclerotic activity. According to Yan et al. (2011) and Chen et al. (2008), dietary garlic supplement boosts the immune system and improves the overall efficiency of pigs. Likewise, the nutritional value of pork for human consumption was generally more favourable (Paschma and Wawrzyński, 2007). The investigations of Omojola et al. (2009) indicated that increasing the garlic level has lowered total cholesterol. Its concentration in the control group was 135.3 mg 100 g^{-1} as compared to 133.3, 66.7 and 44.4 mg 100 g^{-1} in the respective groups with 0.5%, 1% and 1.5% garlic supplementation. In the present study, the significantly lower ($P \leq 0.05$) cholesterol level determined in the *longissimus* muscle of garlic-supplemented pigs may be attributed to saponins and sulfur compounds found in garlic that affect lipid and cholesterol biosynthesis (Konjufca et al., 1997; Omojola et al., 2009). The increased share of omega-3 polyunsaturated fatty acids could partly result from a high content (over 60%) of C18:2 in garlic oil or from an indirect effect of some garlic components on fatty acid metabolism (Kamanna and Chandrasekhara, 1980; Dieumonu et al., 2012).

The significant increase (by about 34%) of liver weight, observed in group III fatteners may be attributed to the biologically active garlic components. A similar increase in liver weight (by 35%) in 8-week-old piglets receiving an aged garlic extract was reported by Tatara et al. (2005).

In conclusion, the incorporation of the prebiotic inulin into fattener diets together with water garlic extract given in drinking water is recommended in the growing period. The benefits include better productive performance, correct blood metabolic profile and potential effect on the composition of fatty acids, which is so important for pork consumers.

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EUGENIUSZ RYSZARD GRELA, KRZYSZTOF PIETRZAK, SANDRA SOBOLEWSKA, PIOTR WITKOWSKI

Efektywność dodatku inuliny i czosnku w żywieniu tuczników

STRESZCZENIE

Celem pracy była ocena wpływu dodatku inuliny oraz inuliny i wodnego wyciągu z czosnku w żywieniu tuczników na efekty produkcyjne, wskaźniki metaboliczne krwi oraz profil kwasów tłuszczowych mięśnia *longissimus*. Doświadczenie przeprowadzono na 48 tucznikach mieszańcach rasy (pbz × wbp) × Duroc o masie początkowej 30±0,5 kg, podzielonych na 3 grupy: I (kontrolna), II (3% inuliny) oraz III (3% inuliny + 500 ml wodnego wyciągu z czosnku w 1000 l wody). Tuczniki otrzymujące dodatek inuliny lub inuliny i czosnku osiągnęły wyższe dobowe przyrosty masy ciała ($P \leq 0,05$) w porównaniu do grupy kontrolnej. Dodatek inuliny i wyciągu wodnego czosnku wpłynął istotnie ($P \leq 0,05$) na obniżenie zawartości cholesterolu we krwi oraz w mięśniu *longissimus*. Zawartość niezbędnych kwasów tłuszczowych omega-3 i omega-6 w mięśniu *longissimus* była najwyższa u tuczników z grupy III.