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THE EFFECT OF ENVIRONMENTAL ENRICHMENT AND SEASON ON THE FATTENING PERFORMANCE, SLAUGHTER VALUE AND SERUM BIOCHEMICAL PARAMETERS OF PIGS

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K e y w o r d s: growing-finishing pigs, management system, season, serum biochemical parameters, carcass quality.

A b s t r a c t

Two pig fattening trials were conducted, one in summer and one in winter. A total of 96 crossbred pigs were analyzed, including 48 animals in each experiment. The pigs were randomly assigned to 4 groups: group 1 – pigs kept in litter-less pens and fed a complete diet *ad libitum*, group 2 – pigs kept in litter-less pens and fed a complete diet supplemented with fresh alfalfa (experiment 1) or alfalfa hay (experiment 2), group 3 – pigs kept in pens with straw bedding and fed a complete diet *ad libitum*, group 4 – pigs kept in pens with straw bedding and fed a complete diet supplemented with fresh alfalfa or alfalfa hay. The body weights of pigs, average daily gains, feed intake, feed conversion ratio, water intake, serum urea nitrogen concentrations and carcass quality were evaluated. Both management systems provided animals with optimal welfare and contributed to highly satisfactory fattening performance and carcass quality. The evaluated systems had no significant effect on average daily gains or slaughter value. However, average daily gains were significantly higher in summer than in winter. Water intake was reduced in pigs fed a complete diet supplemented with fresh alfalfa. Pigs slaughtered in summer were characterized by lower triacyloglicerol level in the blood serum than the animals reared in winter.

WPŁYW WZBOGACANIA ŚRODOWISKA CHOWU I SEZONU NA WARTOŚĆ TUCZNĄ, RZEŹNĄ ORAZ WSKAŹNIKI BIOCHEMICZNE SUROWICY KRWI ŚWIŃ

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S ł o w a k l u c z o w e: tuczniki, system utrzymania, sezon, wskaźniki biochemiczne surowicy krwi, jakość tuszy.

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Abstrakt

Przeprowadzono dwa doświadczenia, pierwsze w sezonie letnim, a drugie w zimowym. Do badań użyto łącznie 96 świń mieszańcowych, po 48 w każdym eksperymencie. Świnie podzielono na 4 grupy doświadczalne i umieszczono w kojcach (4,2 x 3,6 m), zgodnie z układem: gr. 1 – kojce bez ściółki, mieszanka pełnoporcjowa podawana do woli; gr. 2 – kojce bez ściółki, mieszanka pełnoporcjowa i zielonka z lucerny (doświadczenie 1) lub siano z lucerny (doświadczenie 2); gr. 3 – kojce ze ściółką ze słomy, mieszanka pełnoporcjowa podawana do woli; gr. 4 – kojce ze ściółką ze słomy, mieszanka pełnoporcjowa i zielonka lub siano z lucerny. Oceniano masę ciała, średnie przyrosty dobowe, spożycie paszy, zużycie paszy, ilość pobranej wody pitnej, poziom mocznika w surowicy krwi oraz jakość tusz. Zastosowane systemy żywienia i utrzymania zapewniły świniom doświadczalnym wysoki poziom dobrostanu i w związku z tym cechowała je wysoka wartość tuczna i rzeźna, jednak średnie przyrosty dobowe masy ciała tuczników w okresie letnim były wyższe niż w okresie zimowym. Obserwowano mniejsze pobranie wody przez tuczniki otrzymujące zielonkę. Tuczniki ubijane latem charakteryzowały się niższym poziomem triacylogliceroli w surowicy krwi w porównaniu z tucznikami utrzymywanych w sezonie zimowym.

Introduction

In contemporary animal production, intensive pig farming methods are introduced to boost growth and fattening performance. Modern pig farms are characterized by high stocking density, the use of separate buildings for rearing specific production groups, slatted-floor pens without bedding and complete diets (KALLABIS, KAUFMANN 2012, MARSCHANT-FORDE 2009), which can significantly compromise animal welfare.

The 1970s witnessed a growing interest in environmental protection, animal rights and welfare, which have become important issues also in studies investigating the growth performance of pigs (WHITTEMOR 1987). The concept of environmental enrichment has been introduced to animal research, and experiments evaluating the impact of different management systems on pigs from various production groups, in particular sows and piglets, have been carried out (BEATTIE et al. 1995, MILLET et al. 2005, WHITTEMOR 1987). However, studies of the type are still rarely conducted in Poland (GRELA 2008, KARPIESIUK, FALKOWSKI 2009, KARPIESIUK et al. 2013, KOZERA 2007), although environmental enrichment aimed at improving animal welfare is expected to play an increasingly important role in livestock research (KOZERA 2007, LEBRET et al. 2014, ZAPOTOCZNY et al. 2014). The production of large quantities of high-quality pork is determined by the use of high-quality feed, a balanced diet and adequate environmental and management conditions (KARPIESIUK, FALKOWSKI 2008A, WASILEWSKI et al. 2014).

The objective of this study was to analyze the fattening performance, serum biochemical parameters, including blood urea concentrations as an indicator of protein metabolism, and carcass quality of pigs kept in pens with and without bedding, fed a complete diet with or without the addition of roughage.

Materials and Methods

The study comprised two experiments conducted between June and September (summer), and between December and March (winter). The experiments were carried out in a commercial pig farm in a closed production cycle. A total of 96 weaners raised on the farm were used, including 48 animals in each experiment. The animals were produced by simple four-breed crossing that involved F_1 sows (Polish Landrace x Polish Large White) and F_1 boars (Pietrain x Duroc). They were reared in a fattening unit in pens with an area of approximately 15 m^2, with a solid concrete floor, with or without straw bedding. In each trial, the pigs were randomly allocated to 4 treatment groups of 12 animals each:

– group 1 – pigs kept in litter-less pens and fed a complete diet offered *ad libitum*;

– group 2 – pigs kept in litter-less pens and fed a complete diet offered *ad libitum,* which was supplemented with fresh alfalfa in summer and alfalfa hay in winter;

– group 3 – pigs kept in pens with shallow cereal straw bedding and fed a complete diet offered *ad libitum*;

– group 4 – pigs kept in pens with shallow cereal straw bedding and fed a complete diet offered *ad libitum,* which was supplemented with fresh alfalfa in summer and alfalfa hay in winter.

The animals were tagged and divided into treatment groups by the analogue method, based on age, initial body weight and sex. Growing-finishing pigs were fed two complete diets. The diets were formulated to contain 17% crude protein in the first phase of fattening (PT-1 for pigs weighing 30 to 70 kg) and 15% crude protein in the second phase (PT-2 for pigs weighing 70 to 110 kg), according to the Nutrient Requirements of Swine (1993). Feed ingredients were obtained locally. The experimental diets had the following composition: ground wheat (60% in PT-1, 40% in PT-2), ground triticale (13% in PT-1, 28% in PT-2), ground barley (12% in PT-2) and ground oats (7% in PT-1, 5% in PT-2). Protein sources in the diets were protein concentrate and soybean meal. Pigs had free access to feed in automatic dispensers and water in nipple drinkers. In groups 2 and 4, diets were additionally supplemented with fresh alfalfa (1.2 kg per day per pig) and alfalfa hay (0.13 kg per day per pig), provided once daily in metal feeding racks.

The pigs were weighed individually at the beginning of the experiment, during transition from PT-1 to PT-2 diets, and at the end of the fattening period. Concentrate, fresh alfalfa and alfalfa hay intakes were monitored. Water intake was recorded based on readings from water meters. During both experiments, temperature and relative humidity in the fattening unit were measured continuously with the LAB-EL LB-520 hytherograph.

Seven days before slaughter, blood samples for biochemical analyses were collected from the *vena cava cranialis* from each animal. The serum concentrations of protein, urea, total cholesterol, cholesterol fractions and triacylglycerols were determined. The samples were examined in the COBAS INTEGRA 800 chemistry analyzer. Protein content was determined by the biuret method, and urea concentrations were determined in a kinetic test with urease and glutamate dehydrogenase. Total cholesterol and triacylglycerol levels were determined by the enzymatic-colorimetric method, and HDL cholesterol was measured in an enzymatic colorimetric assay. The LDL fraction was calculated based on the following formula: LDL = total cholesterol – LDL – triacylglycerols/5.

Slaughter and carcass quality assessment were carried out in accordance with industrial standards. Lean meat content was determined in hanging hot right half-carcasses with the use of the ultrasound SYDEL SGM apparatus. Half-carcasses are classified according to the EUROP (Commission Regulation (EC) No. 1249/2008) system using a CGM (Capteur Gras/Maigre) apparatus by Sydel, operated by authorized and trained personnel. The CGM is a hand--held device equipped with an optical probe that determines the thickness of the loin muscle and the fat layer by measuring the light reflected in the probe. The device determines the lean meat content of the carcass, i.e. the ratio of the total mass of the striated muscles to the mass of the carcass ($LMC_{CGM} = 59{,}42 + 0{,}1322M_2 - 0{,}6275T_2$ (1); T_2 – the thickness of the backfat between the 3rd and 4th ribs, 6 cm from the line of carcass partition; M_2 – the thickness of the longissimus dorsi muscle, 6 cm from the line of carcass partition), which is weighed no later than 45 minutes after the animal is stunned.

The pH of the LD muscle (*musculus longissimus dorsi)* was measured 45 minutes (pH_{45}) post-mortem and after 24 hours of chilling at 0°C (pH_{24}). pH_{45} and pH_{24} were determined with the use of the WTW 3310 pH meter and combination electrode (WTW-Wissenschaftlich-Technische Werkstaetten GmbH, Weilheim, Germany) and calibrated with the same standard solutions of pH 4.01 and 7.00 at 20°C. Additionally, their accordance was tested with meat samples at the beginning and regularly during the measuring period. Back fat thickness was determined at five points in chilled half-carcasses: at the thickest point above the shoulder, on the back behind the last rib, above the cranial edge of the GM muscle (*musculus gluteus medius*) (first sacral vertebra – sacrum point I), in the midline of the GM muscle (second sacral vertebra – sacrum point II), above the caudal edge of the GM muscle (third sacral vertebra – sacrum point III). The length of the carcass (from the anterior end of the connection between the first rib and the sternum to the anterior end of the symphysis pubis) and loin eye area were measured.

The analyzed animals were housed in groups, therefore, only mean values in groups were determined for the daily intake of feed, alfalfa and water, and the feed conversion ratio. The remaining results were analyzed statistically, and significant differences between means in groups were determined by two-way ANOVA with an orthogonal design and Duncan's test. Analysis was performed using the general lineal model (GLM) procedure of the StatSoft software package (version Statistica PL 12.5). The model of analysis was:

$$Yijk = \mu + FTi + RSj + (FT \times RS)\, ij + \varepsilon ijk$$

where
FTi is the feeding type (i = 1,2), RSj is the rearing systems (j = 1,2),
(FT x RS)ij is the interaction between the treatment and rearing effects, 4ijk is the residual error.

Data were processed with the use of Statistica PL 12.5 software (2015).

Results

The mean temperature inside the fattening unit was determined at 20.9°C in summer and 14.7°C in winter. Mean relative humidity reached 67.8% in summer and 77.1% in winter.

Disease symptoms and animal deaths were not reported during the study.

The fattening period lasted 96 days in summer and 104 days in winter. The average initial body weight of pigs was similar in both experiments, and no statistically significant differences were observed (Table 1). Significant differences in initial body weight were not noted between groups in summer or winter, and average final body weight was determined at 113.8 kg in summer and 108.8 kg in winter (Table 2). The differences between the mean values of this trait were statistically significant ($p \leq 0.05$). The animals were characterized by a high growth rate, and highly significant differences were observed between seasons – average daily gain was 125 g higher in summer than in winter. The average daily gains of all animals ranged from 794 g in winter in pigs kept in litter-less pens and fed a complete diet to 968 g in summer in pigs housed in pens with bedding and fed a complete diet supplemented with fresh alfalfa. No significant differences in average daily gains were noted between groups in each season. However, highly significant differences were observed between seasons, and average daily gains were considerably higher in summer.

Average feed consumption per kg of body weight gain reached 2.70 kg in summer and 2.85 kg in winter (Table 1).

Table 1

The effect of environmental enrichment, season and dietary alfalfa supplementation on the fattening performance of pigs

Specification	Season*	Pens without bedding		Pens with bedding		Mean**
		complete diet	complete diet + alfalfa	complete diet	complete diet + alfalfa	
Initial body weight [kg]	*S*	23.0	22.9	23.1	22.9	22.9
	W	23.7	23.2	23.4	23.1	23.3
Final body weight at slaughter [kg]	*S*	114.1	114.6	110.5	115.9	113.8^{a}
	W	106.3	107.6	109.7	111.5	108.8^{b}
Average daily gain [g]	*S*	948	955	911	968	946^{A}
	W	794	811	830	849	821^{B}
Daily feed intake [kg]	*S*	2.58	2.58	2.48	2.60	2.56
	W	2.23	2.32	2.40	2.43	2.18
Daily intake of fresh alfalfa [kg]	*S*	–	1.20	–	1.20	1.2
Daily intake of alfalfa hay [kg]	*W*	–	0.14	–	0.12	0.13
Daily water intake per pig [L]	*S*	5.74	4.57	5.41	4.09	4.95
	W	6.06	5.52	5.79	5.57	5.73

* Season: *S* – summer; *W* – winter

** Means within a column without a common superscript differ significantly ($^{a, b}$ – $P < 0.05$; ^{A,B} – $P < 0.01$)

In the experiments conducted in summer and winter, the applied housing systems (with and without bedding) and feeding regimes (complete diets with or without the addition of roughage) had no significant influence on the fattening performance, growth rates or slaughter value of pigs. All of the evaluated management systems supported the production of carcasses characterized by a high lean meat content, high quality and processing suitability.

The lowest average daily water intake of 4.57 L and 4.09 L was noted in the summer experiment in groups whose diets were supplemented with fresh alfalfa (groups 2 and 4, respectively) – Table 1. Reduced water intake in summer can probably be attributed to the high water content of fresh alfalfa.

The average values of serum biochemical parameters were generally within the reference range, and the only parameter that exceeded the norm was total serum cholesterol measured in summer (Table 2). It should be noted, however, that reference values (WINNICKA 2015) do not account for differences between the age groups or production groups of animals. Pigs slaughtered in summer were characterized by lower triacylglycerol levels in the blood serum than the animals reared in winter.

Table 2

The effect of environmental enrichment, season and dietary alfalfa supplementation on the serum concentrations of blood urea nitrogen and lipids [mmol/L] in pigs

Specification	Season*	Pens without bedding		Pens with bedding		Mean***
		complete diet	complete diet + alfalfa	complete diet	complete diet + alfalfa	
Blood urea nitrogen	*S*	4.98**	5.87^{A}	4.50^{B}	5.29	5.16^{a}***
	W	5.89	5.45	5.58	5.72	5.66^{b}
Total cholesterol	*S*	2.38	2.26	2.38	2.34	2.34^{A}
	W	1.90	1.86	1.89	1.76	1.86^{B}
HDL cholesterol	*S*	1.18	1.09	1.09	1.23	1.15^{A}
	W	1.09^{a}	1.06^{a}	1.03	0.88^{b}	1.02^{B}
LDL cholesterol	*S*	1.09	1.05	1.14	1.05	1.08^{A}
	W	0.67	0.65	0.73	0.78	0.71^{B}
Triacylglycerols	*S*	0.28	0.29	0.30	0.24	0.28
	W	0.35	0.37	0.29	0.25	0.32

* Season: *S* – summer; *W* – winter

** Means within a row without a common superscript differ significantly (^{a,b} – $P < 0.05$; ^{A,B} – $P < 0.01$)

*** Means within a column without a common superscript differ significantly (^{a,b} – $P < 0.05$; ^{A,B} – $P < 0.01$)

In winter, significant differences were observed in HDL-C concentrations between group 1 (1.09 mmol/L) and group 2 (1.06 mmol/L) vs. group 4 (0.88 mmol/L). Total cholesterol (2.34 mml/L), HDL-C (1.15 mml/L) and LDL-C (1.08 mml/L) levels were highly significantly higher ($p \leq 0.01$) in summer than in winter when the respective values were determined at 1.86, 1.08 and 0.71 mmol/L. Serum triacylglycerol levels were below the average reference values reported by WINNICKA (2015), and they reached 0.28 and 0.32 mmol/L in summer and winter, respectively

In summer, serum urea concentrations differed significantly between group 2 (5.87 mmol/L) and group 3 (4.50 mmol/L). The increase in urea levels in group 2 can be attributed to higher feed and green forage intake and, consequently, higher protein intake (Table 1).

The dietary treatments had no significant influence on slaughter traits or meat quality in either experiment (Table 3). Lean meat percentage, loin eye area, carcass length and pH_{45} were not significantly affected by the season, feeding regime or housing system. Carcasses from the summer experiment were characterized by significantly higher back fat thickness in all measurement points and higher pH_{24} values (Table 3) than carcasses from the winter experiment. PSE or partially PSE meat was not observed, and active acidity (pH_{45}) was high in all analyzed carcasses in both seasons, ranging from 6.02 in summer to 6.26 in winter. pH is measured 24 hours (pH_{24}) after slaughter to determine the presence of DFD (dark, firm, dry) meat with pH higher than 6.2.

In the present study, DFD meat was not detected, and the average value of pH_{24} ranged from 5.43 in carcasses produced in summer to 5.42 in carcasses produced in winter.

Table 3
The effect of environmental enrichment, season and dietary alfalfa supplementation on the carcass characteristics of pigs

Specification	Season*	Pens without bedding		Pens with bedding		Mean**
		complete diet	complete diet + alfalfa	complete diet	complete diet + alfalfa	
Lean meat percentage	*S*	55.61	55.55	55.04	55.15	55.33**
	W	56.09	56.41	55.52	55.42	55.86
Back fat thickness*** [mm]	*S*	22.80	22.70	23.18	24.90	23.39^{A}
	W	15.90	18.20	14.50	17.60	16.59^{B}
Loin eye area [cm^2]	*S*	55.50	54.70	54.20	52.20	54.19
	W	52.60	55.20	53.30	54.30	53.18
Carcass length [cm]	*S*	83.83	83.50	83.33	83.91	83.64
	W	81.60	83.20	82.20	83.80	82.73
pH_{45min}	*S*	6.53	6.64	6.58	6.67	6.61
	W	6.52	6.59	6.54	6.64	6.57
$pH_{24\ h}$	*S*	5.56	5.54	5.53	5.57	5.55^{A}
	W	5.46	5.49	5.49	5.48	5.48^{B}

* Season: *S* – summer; *W* – winter
** Means within a column without a common superscript differ significantly ($P < 0.01$)
*** Mean values of five measurements.

Discussion

In this study, temperature and humidity in the fattening unit were generally consistent with industrial standards for growing-finishing pigs (KOŁACZ, DOBRZAŃSKI 2006). CHMIELOWIEC-KORZENIOWSKA et al. (2012) reported greater variations in temperature and relative humidity in pens with deep litter in summer and winter seasons.

Average daily gains noted in our study were similar to those reported by JORDAN et al. (2008) and MILLET et al. (2005). In other experiments conducted in recent years, both lower (JORDAN et al. 2008, KARPIESIUK, FALKOWSKI 2008a, KOZERA 2007, LEBRET et al. 2014) and higher (CHMIELOWIEC-KORZENIOWSKA et al. 2012) daily weight gains were noted in growing-finishing pigs. In a study by LEBRET et al. (2006), season had a significant ($P < 0.001$) influence on pig growth rates. In the cited study, the highest weight gains were reported in winter, the lowest weight gains were noted in summer, whereas medium weight gains that did not differ significantly from the reported values were observed in spring. In the work of BRZOZOWSKI et al. (2013) who analyzed the

influence of effective microorganisms on fattening performance, average daily gains in both experimental groups were similar to those noted in our winter experiment, but lower by 100 g and 133 g than in our summer experiment.

KORNIEWICZ et al. (2001), who studied growing-finishing pigs from commercial four-breed crossing, reported slightly lower average feed consumption per kg of body weight gain (2.67 kg). In the previously cited French study (LEBRET et al. 2006), the management system had no significant effect on the feed conversion ratio which was determined at 3.07, 3.27 and 3.30 kg/kg in winter, spring and summer, respectively.

In the Nutrient Requirements of Swine published by the US National Research Council (2012), the minimum water demand of growing-finishing pigs was set at 2 L per kg of a complete diet. Pigs fed *ad libitum* usually drink approximately 2.5 L of water per kg of a complete diet. In growing pigs, water intake can be influenced by environmental factors, diet composition, the health status of animals and stress exposure (SHAW et al. 2006). The relationship between fresh alfalfa intake and reduced water intake had been established in earlier studies (KARPIESIUK, FALKOWSKI 2008b, KARPIESIUK, FALKOWSKI 2009).

In a study into the compensatory growth of growing-finishing pigs, WIĘCEK et al. (2008) demonstrated lower concentrations of total cholesterol and LDL-C in animals whose diets were restricted in the first phase of fattening, compared with pigs fed semi *ad libitum* diets, regardless of the type of administered diets.

Similar or slightly higher triacylglycerol concentrations were reported in previous studies of growing-finishing pigs of the same genotype (EGGUM 1970, KARPIESIUK, FALKOWSKI 2008b). GRELA et al. (2012) supplemented pig diets with inulin and garlic and observed a drop in the serum concentrations of total cholesterol, LDL-C and triacylglycerols as well as an increase in HDL-C levels. In another study, GRELA et al. (2013) reported an increase in total cholesterol and LDL-C levels in pigs fed an organic diet supplemented with fish meal and premix. A reduction in triacylglycerol, total cholesterol and LDL-C concentrations in the blood and tissues of pigs could improve the nutritional value of pork.

According to the literature, excessive protein intake increases urea synthesis and secretion, which is manifested by higher urea concentrations in the blood serum (EGGUM 1970, WIĘCEK et al. 2008). SEMENIUK, GRELA (2011) reported (throughout the fattening period) lower values of protein metabolism parameters, including the plasma levels of total protein, uric acid, blood urea nitrogen (BUN) and ammonia, in growing-finishing pigs fed diets with 10% reduced protein content in comparison with animals whose protein intake was consistent with the Polish edition of the Nutrient Requirements of Swine (1993)

The pH_{45} values noted in our study are indicative of normal meat acidity, according to KORTZ (2001). In a study investigating the influence of different pig management systems on meat quality and the fatty acid profile of the LD muscle, KARPIESIUK et al. (2013) reported much greater variations in pH45 values (5.80 – 6.70) in comparison with the present findings. In the above study, pH_{24} values were determined in the range of 5.35 to 5.61 and were similar to our results. In the work of KARPIESIUK, FALKOWSKI (2009), pH_{45} and pH_{24} values were lower than those noted in the present study.

Conclusions

Fattening performance and carcass quality values were satisfactory and remained within the reference ranges in all experimental groups of growing--finishing pigs raised in summer and winter.

Dietary supplementation with fresh alfalfa reduced water intake by pigs.

The average daily gains of pigs were determined at 946 g in summer (first experiment) and 821 g in winter (second experiment).

The evaluated carcasses were characterized by a satisfactory or highly satisfactory lean meat content. The average lean meat percentage was determined at 55.33% in the first experiment and 55.86% in the second experiment, and the difference between the noted values was not statistically significant.

It can be concluded that environmental enrichment did not improve the fattening performance of pigs.

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