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Effect of inulin extraction method and level in growing-finishing pig diets on performance, carcass traits and nutrients digestibility

Wpływ metody ekstrakcji i poziomu inuliny w mieszankach dla tuczników na efekty produkcyjne, wartość rzeźną tusz oraz strawność składników pokarmowych

Summary. The effectiveness of fatteners` diet supplementation with three levels of inulin (10, 20 and 30 g/kg mixture) obtained from water or water-alcohol extraction was assessed. The studies included 140 crossbred pigs (PL × PLW) × Duroc of 25 ±0.5 kg initial body weight. The animals were assigned into 7 treatment groups, whose diets, besides the control, comprised different contents of inulin (10, 20 and 30 g) as water extracts (II, III and IV) or water-alcohol extracts (V, VI, VII). Fatteners' performance, carcass traits and nutrient digestibility were evaluated during two fattening periods (grower and finisher) as well as at slaughter. Dietary inclusion of 20 g water-extracted inulin or 30g water-alcohol extracts improved the daily weight gain throughout the whole fattening period ($p \leq 0.05$). The fatteners from these groups showed the best feed conversion, too. Generally, no significant correlations were reported between the extraction method and the studied traits, whereas a different inulin level affected the daily weight gain, feed intake or crude fiber digestibility.

Key words: inulin, growing-finishing pig, ADG, FCR, carcass trait, nutrient digestibility

INTRODUCTION

Antibiotic growth promoters (AGPs) have been highly effective at keeping pigs healthy, producing more meat per kilogram of feed. However, the European Union ban on using antibiotic growth stimulators resulted in intensification of research on alternatives to AGPs that could maintain animal health and performance. One of the supplements, which demonstrated positive impact on gut integrity, thereby improving animal

performance, is a group of natural nutritional additives [Verdonk 2005]. Prebiotics (e.g. inulin) have been known for years, but there is still not many papers about the research on the use of this supplement in animal nutrition.

Inulin, as a prebiotic, resists enzymatic digestion in the upper gastrointestinal tract, it reaches the colon virtually intact to undergo bacterial fermentation. All inulin-type prebiotics are bifidogenic. They stimulate the growth of beneficial species of bacteria [Kelly 2008]. It is important to know how much inulin needs to be added to the feed to get the best results in both, fattening and quality of produced meat, from the perspective of manufacturers.

The aim of the present experiment was to 1) investigate whether diets incorporating inulin could improve production effects, carcass traits and nutrient digestibility, 2) determine the appropriate amount of inulin for growing-finishing pigs, 3) examine if a method of inulin extraction or its different content affect the nutritional effects. The hypothesis tested was that an inulin-supplemented diet would help achieve better results in fattening pigs.

MATERIAL AND METHODS

The experiment involved 140 crossbred pigs (PL × PLW) × Duroc with an initial body weight of 25.0 ±0.5 kg. Animals were divided into 7 groups, kept in pens (4 pigs per pen). Fatteners were fed the following mixtures – grower (25–70 kg BW) and finisher (71–115 kg BW). The diets comprised ground grain (wheat and barley), soybean meal, soybean oil, mineral feeds (salt, monocalcium phosphate and ground limestone) and mineral-vitamin premix. The feeds were balanced for metabolizable energy, total protein, amino acid composition, minerals and vitamins [Grela *et al.* 2009]. Diet for group I (control) was composed without inulin addition, other groups received 1%, 2% and 3% of inulin in mixture (water or water-alcohol extraction of inulin from chicory roots, respectively) (Table 1). All animals had free access to feeders (*ad libitum* consumption) and drinkers. The hygienic conditions, that is: temperature, relative humidity and cooling were the same for all the groups.

Inulin was extracted according to the modified Stahl and Schild method [1981]. Inulin purity is presented in Table 1.

During the experiment animals were weighed 3 times (at the start, at 70 kg BW and before slaughter). Feed intake was controlled individually by weighing portions for automatic feed in individual cages.

The digestibility study was carried out on 6 animals in each group. Animals during the experiment were kept in individual metabolic cages, which allowed feed intake control and fecal sample collection. Nutrient digestibility was evaluated using the Cr_2O_3 indicator. Fecal samples were collected 2 times for 3 days. Stool samples taken during 2 periods (growing 40-45 kg BW and finishing 90–95 kg BW) as well as intestinal samples (after slaughter) were examined to estimate nutrient digestibility. The amount of Cr_2O_3 was determined according to the procedure described by Kimura and Miller [1957] and nutrient content as per AOAC methods [2000].

The pigs were slaughtered at about 115 kg BW. The slaughter was conducted in accordance with the technology currently employed in meat industry, using the electrical

stunning. Carcass and liver were weighed and the content of meat in carcass was measured. Backfat thickness was estimated over the shoulder, back and in three sites on the cross.

Table 1. Experimental design
Tabela 1. Układ doświadczenia

Specification Wyszczególnienie	Feeding groups – Grupy żywieniowe						
	I	II	III	IV	V	VI	VII
Inulin additive g/kg feed (water extraction)[1] Dodatek inuliny g/kg paszy (ekstrakcja wodna)[1]	0	10	20	30	0	0	0
Inulin additive g/kg feed (water-alcohol extraction)[2] Dodatek inuliny g/kg paszy (ekstrakcja wodno-alkoholowa)[2]	0	0	0	0	10	20	30
Number of animals Liczba zwierząt	20	20	20	20	20	20	20

[1] Content: inulin (~92%), glucose/fructose/sucrose (~8%)
[2] Content: inulin (~89%), glucose/fructose/sucrose (~8%), other sugar (~1%), polyphenols (~2%)
[1] Zawartość: inulina (~92%), glukoza/fruktoza/sacharoza (~8%)
[2] Zawartość: inulina (~89%), glukoza/fruktoza/sacharoza (~8%), inne cukry (~1%), polifenole (~2%)

The results were subjected to analysis of variance (ANOVA) to provide mean values for the groups, while significance of differences for the mean values of the studied traits was established with Duncan's test using Statistica package. All feeding groups receiving inulin addition were compared with control. Besides, the extraction methods and dietary inulin level were compared.

RESULTS

Production effects of fatteners with dietary inulin supplementation are summarized in Table 2. A significantly higher feed intake was noted in the groups with 1% and 3% inulin dietary additive. During the whole fattening period, slightly better values for daily weight gain were obtained in the groups with polysaccharide additive (significantly higher in group III and VII, $p \leq 0.05$). This obviously resulted in feed intake increase, but for the whole fattening period, feed conversion ratio (FCR) was lower for most groups receiving prebiotic (the best results were also reported in group III and VII). A different method of inulin extraction did not affect daily weight gain, feed intake or feed conversion ratio for the whole fattening period (25–115 kg). Employment of a different inulin level was found to have noticeable influence of daily gains ($p \leq 0.05$). Considering the whole fattening period, the best results were reported for young animals whose diet was supplemented with 2% and 3% of prebiotics, irrespective of its extraction procedure. However, different inulin content did not contribute to feed conversion at each fattening stage. The mean values for faecal (at two periods growing and finishing) and ileal digesti-

Table 2. Daily gains, feed intake and feed conversion ratio in growing-finishing pigs
Tabela 2. Przyrosty dzienne, pobranie i wykorzystanie paszy przez tuczniki

Specification Wyszczególnienie	Fattening period, kg Okres tuczu,	Feeding groups Grupy żywieniowe							Extraction methods Metody ekstrakcji		Dietary inulin level, g/kg Poziom inuliny w paszy			
		I	II	III	IV	V	VI	VII	water woda	water- alcohol woda-alkohol	0	10	20	30
Feed intake, kg/day Pobranie paszy, kg/dzień	25-70	2.22	2.15	2.39	2.41	2.32	2.32	2.31	2.32	2.32	2.22	2.24	2.36	2.36
	70-115	3.02^{b}	3.35^{a}	3.19^{ab}	3.31^{a}	3.35^{a}	3.21^{ab}	3.31^{a}	3.28	3.29	3.02^{b}	3.35^{a}	3.20^{ab}	3.31^{a}
	25-115	2.62^{b}	2.75^{ab}	2.79^{ab}	2.86^{a}	2.84^{a}	2.77^{ab}	2.81^{a}	2.80	2.81	2.62^{b}	2.80^{a}	2.78^{ab}	2.84^{a}
Daily weight gains, g Przyrosty dzienne	25-70	768^{c}	758^{c}	886^{ab}	774^{c}	815^{bc}	865^{b}	925^{a}	806^{b}	868^{a}	768^{b}	787^{b}	876^{a}	850^{a}
	70-115	781^{c}	1058^{a}	870^{bc}	932^{b}	761^{c}	804^{c}	782^{c}	953^{a}	782^{b}	781^{c}	910^{a}	837^{bc}	857^{b}
	25-115	772^{b}	849^{ab}	881^{a}	822^{ab}	799^{b}	846^{ab}	882^{a}	851	842	772^{b}	824^{ab}	864^{a}	852^{a}
Feed conversion ratio, kg/kg Zużycie paszy	25-70	2.89^{ab}	2.84^{b}	2.70^{bc}	3.11^{a}	2.85^{b}	2.68^{bc}	2.50^{c}	2.88	2.68	2.89	2.85	2.69	2.81
	70-115	3.87^{bc}	3.17^{d}	3.67^{bc}	3.55^{c}	4.40^{a}	3.99^{b}	4.23^{ab}	3.46^{b}	4.21^{a}	3.87	3.79	3.83	3.89
	25-115	3.39^{ab}	3.24^{ab}	3.17^{b}	3.48^{a}	3.55^{a}	3.27^{ab}	3.19^{b}	3.30	3.34	3.39	3.40	3.22	3.34

a, b, c, d – values in a row with different letters are significantly different ($p \leq 0.05$)
a, b, c, d – wartości oznaczone różnymi literami w wierszu różnią się istotnie ($p \leq 0,05$)

Table 3. Coefficient of total tract apparent digestibility (%) for growing period (40–45 kg BW)
Tabela 3. Współczynniki strawności kałowej (%) w okresie grower owym (40–45 kg)

Component Składnik	Feeding groups Grupy żywieniowe							Extraction methods Metody ekstrakcji		Dietary inulin level, g/kg Poziom inuliny w paszy, g/kg			
	I	II	III	IV	V	VI	VII	water woda	water-alcohol woda-alkohol	0	10	20	30
Crude protein/Białko ogólne	78.8	78.9	79.0	79.1	78.8	78.9	78.8	79.0	78.8	78.8	78.9	79.0	78.9
Crude fat/Tłuszcz surowy	62.6	61.9	62.1	62.5	62.4	61.9	62.2	62.2	62.2	62.6	62.2	62.0	62.4
Crude fibre/Włókno surowe	13.8^{b}	14.5^{ab}	14.9^{ab}	15.0^{ab}	13.9^{b}	14.7^{ab}	15.3^{a}	14.8	14.6	13.8^{b}	14.2^{ab}	14.8^{ab}	15.2^{a}
Nitrogen-free extract Bezazotowe wyciągowe	91.6	91.4	91.3	90.8	91.5	91.6	91.4	91.2	91.5	91.6	91.5	91.5	91.1

a, b – values in a row with different letters are significantly different ($p \leq 0.05$)
a, b – wartości oznaczone różnymi literami w wierszu różnią się istotnie ($p \leq 0,05$)

tab. 4, 5

Table 4. Coefficient of total tract apparent digestibility (%) for finishing period (90–95 kg BW)
Tabela 4. Współczynniki strawności kałowej (%) w okresie finiszerowym (90–95 kg)

Component Składnik	Feeding groups Grupy żywieniowe							Extraction methods Metody ekstrakcji		Dietary inulin level, g/kg Poziom inuliny w paszy, g/kg			
	I	II	III	IV	V	VI	VII	water woda	water-alcohol	0	10	20	30
Crude protein Białko ogólne	84.4	84.8	84.9	85.1	84.8	85.1	85.5	84.9	85.1	84.4	84.8	85.0	85.3
Crude fat Tłuszcz surowy	75.3	76.1	75.7	76.0	75.9	76.1	76.4	75.9	76.1	75.3	76.0	75.9	76.2
Crude fibre Włókno surowe	33.1^{b}	33.8^{ab}	34.0^{ab}	35.5^{ab}	34.2^{ab}	34.8^{ab}	36.0^{a}	34.4	35.0	33.1^{b}	34.0^{ab}	34.4^{ab}	35.8^{a}
Nitrogen-free extract Bezazotowe wyciągowe	93.8	93.9	93.7	93.7	93.7	93.5	93.5	93.8	93.6	93.8	93.8	93.6	93.6

a. b – values in a row with different letters are significantly different ($p \leq 0.05$)
a. b – wartości oznaczone różnymi literami w wierszu różnią się istotnie ($p \leq 0,05$)

Table 5. Coefficient of ileal digestibility (%) at slaughter (115 kg BW)
Tabela 5. Współczynniki strawności jelitowej (%) przy uboju (115 kg)

Component Składnik	Feeding groups Grupy żywieniowe							Extraction methods Metody ekstrakcji		Dietary inulin level, g/kg Poziom inuliny w paszy, g/kg			
	I	II	III	IV	V	VI	VII	water woda	water-alcohol woda-alkohol	0	10	20	30
Crude protein/Białko ogólne	78.8	78.9	79.0	79.1	78.8	78.9	78.8	79.0	78.8	78.8	78.9	79.0	78.9
Crude fat/Tłuszcz surowy	62.6	61.9	62.1	62.5	62.4	61.9	62.2	62.2	62.2	62.6	62.2	62.0	62.4
Crude fibre/Włókno surowe	13.8^{b}	14.5^{ab}	14.9^{ab}	15.0^{ab}	13.9^{b}	14.7^{ab}	15.3^{a}	14.8	14.6	13.8^{b}	14.2^{ab}	14.8^{ab}	15.2^{a}
Nitrogen-free extract Bezazotowe wyciągowe	91.6	91.4	91.3	90.8	91.5	91.6	91.4	91.2	91.5	91.6	91.5	91.5	91.1

Table 6. Carcass and liver weight, meat content (%) and backfat thickness
Tabela 6. Masa tuszy, wątroby, mięsność (%) i grubość słoniny grzbietowej

Component Składnik		Feeding groups Grupy żywieniowe							Extraction methods Metody ekstrakcji		Dietary inulin level, g/kg Poziom inuliny w paszy, g/kg			
		I	II	III	IV	V	VI	VII	Water	Water-alcohol	0	10	20	30
Carcass weight, kg Masa tuszy		81.70^{ab}	83.83^{a}	82.63^{a}	80.83^{b}	79.82^{b}	81.35^{ab}	83.23^{a}	82.43	81.47	81.70	81.83	81.99	82.03
Meat content, % Mięsność		52.4	52.7	53.1	52.3	53.1	53.5	52.4	52.7	53.0	52.4	52.9	53.3	52.4
Liver weight, g Masa wątroby		1486	1537	1545	1492	1422	1515	1534	1525	1490	1486	1480	1530	1513
Backfat thickness, mm Grubość słoniny	shoulder łopatka	34.3	34.7	34.2	35.8	34.5	35.2	35.5	34.9	35.1	34.3	34.6	34.7	35.7
	mid back grzbiet	23.1	23.5	24.2	24.1	23.5	22.8	23.6	23.9	23.3	23.1	23.5	23.5	23.9
	cross 3 measurements krzyż, 3 pomiary	15.3	16.1	16.7	15.4	15.1	15.6	16.4	16.1	15.7	15.3	15.6	16.2	15.9
	mean for five measurements średnia z 5 pomiarów	24.2	24.8	25.0	25.1	24.4	24.5	25.2	25.0	24.7	24.2	24.6	24.8	25.1

a, b – values in a row with different letters are significantly different ($p \leq 0.05$)
a, b – wartości oznaczone różnymi literami w wierszu różnią się istotnie ($p \leq 0,05$)

bility (at the slaughter), were similar (Tables 3–5). The only significant difference was observed for crude fiber in the growing and finishing period, but, notably, different extraction methods of inulin did not cause any significant differences. As for the growing period, the highest total tract apparent digestibility rate for crude fiber was recorded for group VII (with 3% water-alcohol extracted inulin) and the value was significantly higher ($p \leq 0.05$) as compared to control and group V (with 1% water-alcohol inulin extract). The lowest value of this ingredient in total tract apparent digestibility examined during the finishing period was calculated for the control group and the highest value in group VII with 3% inulin additive to mixture. The difference between these two groups proved significant ($p \leq 0.05$). Application of 3% inulin has significantly increased the digestibility coefficient for crude fiber as against the group whose diet did not contain the prebiotic feed supplement There were not noted any significant changes in the mean coefficients of ileal digestibility.

No significant differences were reported in meat content and liver weight between the animals from the experiment (Table 6). The lowest carcass weight had the animals from group IV and V and the differences shown in the comparison to group II, III and VII were statistically significant ($p \leq 0.05$).Although there were not found significant differences in backfat thickness between the treatment groups, it tends to commonly increase with a growing inulin content in diet. Comparing the inulin extraction methods or only its feed percentage, it may be concluded that they do not have any significant effect on the weight of carcass, liver and fattener meat content.

DISCUSSION

In the study on fatteners, Kjos *et al.* [2009] observed an increase in weight gain in the first and second period of fattening along with an elevating inulin level in feed. A similar relationship was reported by Frantz *et al*. [2003] in the experiment involving a total of 252 weanling pigs. However, the authors concluded that inulin cannot be considered suitable replacement for antibiotics to improve growth/performance in nursery pigs. In our study, we have obtained slightly better results in production effects of fatteners, i.e., higher daily weight gain but not statistically significant for all of the applied mixtures.

The Jolliff and Mahan studies [2012] showed that inulin did not affect macromineral digestibility. The researches carried out by Ratriyanto *et al*. [2009] also indicated that this prebiotic addition did not modify ileal and total tract nutrient digestibility in piglets.In our experiment, only one significant difference in crude fibre faecal digestibility for growing and finishing period was found. Speaking generally, there is a lack of information on the effect of inulin on the nutrient digestion. The studies by Vanhoof and De Schrijver [1996], Houdijk *et al.* [1999] and De Schrijver and De Vos [2003] established that inulin and oligofructose supplementation does not affect protein digestion or nitrogen retention.

Carcasses from pigs [Ponnampalam *et al.* 2009] fed inulin diets were heavier (65.15 vs 62.90 kg) when compared to the diets without inulin content. The increase in average daily gain and final live weight in fact resulted in larger carcass weight as against the

non- inulin feeding group. In the present study, the carcasses in group II, III and VII were heavier than in control, but differences were insignificant.

The use of different prebiotics was found to have a positive effect on the backfat thickness in finishing pigs in few experiments. Grela *et al.* [2001] reported that backfat thickness was significantly reduced in growing-finishing pigs fed the diets supplemented with mannanoligosaccharide (5 g kg^{-1} of diet). The research of Zhou *et al.* [2007] showed that a dose of 5 g kg^{-1} of dietary chitosan (linear polysaccharide) resulted in lower average backfat thickness of finishing pigs. The findings highlighted that some prebiotics decrease the serum lipids levels and fat deposition of pigs. The lipid lowering mechanisms in response to prebiotics (e.g. fructooligosaccharides, inulin) have been proposed in rats and humans. The triacylglycerol-lowering action of oligofructose occurs due to the reduction in de novo fatty acid synthesis in the liver [Delzenne and Kok 1999, Letexier *et al*. 2003, Kang *et al.* 2006]. In our research, inulin addition did not modify backfat thickness significantly.

CONCLUSION

The use of inulin supplementation in the present study has improved significantly some of the studied traits. However, it is still challenging to give definite amount of inulin additive which would be most appropriate for fattener nutrition. Therefore, it seems important to conduct more extensive research on the effects of inulin in pig nutrition as there are only few core publications addressing this supplement application. On the grounds of the present study, it can be stated that that various methods of inulin extraction do not affect the studied traits but different levels of inulin certainly do.

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Streszczenie. Oceniono efektywność dodatku 3 dawek inuliny (10, 20 i 30 g/kg mieszanki) pochodzącej z ekstrakcji wodnej lub wodno-alkoholowej w mieszankach dla tuczników. Eksperyment obejmował 140 świń mieszańców (wbp × pbz) × duroc o początkowej masie ciała 25,0 ±0,5 kg. Zwierzęta podzielono na 7 grup, gdzie oprócz kontroli zastosowano różny udział inuliny (10, 20 i 30 g) pochodzącej z ekstrakcji wodnej (grupa II, III i IV) lub wodno-alkoholowej (grupa V, VI i VII). Oszacowano efekty produkcyjne, wartość rzeźną tusz oraz strawność składników pokarmowych w dwóch okresach tuczu (grower i finiszer) oraz przy uboju. Zastosowanie 20 g inuliny z wyciągu wodnego lub 30 g wyciągu wodno-alkoholowego zwiększyło przyrosty dzienne w odniesieniu do całego okresu tuczu ($p \leq 0,05$). Tuczniki z tych grup charakteryzowały się również najlepszym wykorzystaniem paszy. Generalnie nie odnotowano istotnych zależności pomiędzy metodą ekstrakcji a badanymi cechami, podczas gdy różny poziom inuliny wpłynął na dzienne przyrosty, pobranie paszy oraz strawność włókna surowego.

Słowa kluczowe: tuczniki, inulina, przyrosty, zużycie paszy, wartość rzeźna tuszy, strawność składników pokarmowych