Ann. Anim. Sci., Vol. 14, No. 4 (2014) 911–920 *DOI: 10.2478/aoas-2014-0046*

DE GRUYTER
OPEN

THE EFFECT OF INULIN EXTRACTION METHOD OR POWDER FROM INULIN-PRODUCING PLANTS IN FATTENER DIETS ON PERFORMANCE, CARCASS TRAITS AND MEAT QUALITY*

Sandra Sobolewska, Eugeniusz R. Grela♦

Institute of Animal Nutrition and Bromatology, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin, Poland
♦Corresponding author: ergrela@interia.pl

Abstract

Inulin or plant materials containing this polysaccharide are deemed interesting additives to feed mixtures for pigs. The experiment was conducted with 120 weaners, hybrids of (PLW × PL) × Duroc breeds with the initial body weight of 30.0±0.5 kg, which were divided into 5 feeding groups. Inulin was added to feed mixtures in the following forms: 2% inulin obtained from chicory roots with two extraction methods: water (group II) and water-alcohol (group III), and 4% powder from Jerusalem artichoke tubers (group IV) or from chicory roots (group V). Body weight of the animals and feed intake were controlled at two-week intervals, and carcasses were analysed post-slaughter. Determinations were carried out for physicochemical properties of *longissimus dorsi* muscle of fatteners. Additional measurements were made for pH value, electrical conductivity and colour (CIE L*a*b* system) of fresh and thermally-treated meat samples. The highest body weight gains were recorded in group IV (powder from Jerusalem artichoke tubers) and group II (water additive of inulin). Dietary inclusion of both types of powders contributed to decreased thickness of backfat. The study showed also the effect of adding inulin or inulin-producing materials on the quality of raw and cooked pork. Significant differences between the control and experimental groups were demonstrated for hardness, chewiness and gumminess of cooked meat. The highest colour saturation (L* and b*) and hue value were noted in raw loin of the fatteners administered feed mixtures with inulin from water-alcohol extraction. Inclusion of 2% inulin preparation with differing degrees of polymerization (water or water-alcohol extraction) or inulin-producing materials (topinambur or chicory powder) in fattener diets is likely to improve animal performance, but the application of Jerusalem artichoke appears to be more justified.

Key words: inulin, pig, performance, carcass, meat quality

Rational nutrition of pigs, including the use of new-generation feed additives, enables the production of pork characterized by high culinary and technological qual-

*The paper supported by the project No. 12 006710 from the National Centre of Research and Development.

ity (Rosenvold and Andersen, 2003; Dugan et al., 2004). In both scientific research and practice of pig rearing, worthy of notice are pro- and prebiotics whose addition to feed mixtures may contribute to the improvement of the health status of animals and their production performance (Frantz et al., 2003; Grela, 2006; Samanta et al., 2013). Among prebiotics, high interest is observed in oligosaccharides, including inulin and other fructooligosaccharides (Coumssement, 1999; Flickinger et al., 2003; Hansen et al., 2008; Ponnampalam et al., 2009; Zhao et al., 2013). It is due to specific colonic fermentation of dietary carbohydrates by bifidobacteria, which are capable of breaking down and utilizing inulin-type fructans. This mechanism is attributed to a β-fructofuranosidase gene that the bifidobacteria possess, providing them with a competitive advantage over other microorganisms in a complex microbiota such as the gut (Playne and Crittenden, 1996). Bifidobacteria exert a wide range of effects such as inhibition of pathogen growth, production of digestive enzymes, modulation of the immune response, and restoration of microbial integrity of the gut microbiota following antibiotic therapy or antibiotic-associated diarrhea (Bernet et al., 1993; McCracken and Gaskins, 1999). Inulin changes the intestinal microbiota and short-chain fatty acid concentrations in growing pigs irrespective of their basal diet (Loh et al., 2006). The most popular sources of inulin include tubers of Jerusalem artichoke (*Helianthus tuberosus*) and roots of chicory (*Cichorium intybus*) (Kjos et al., 2010; Van Loo, 2007; Vhile et al., 2012; Yan et al., 2011). Investigations carried out so far show disparity in results regarding production effects and selected attributes of meat quality (Hansen et al., 2008; Ponnampalam et al., 2009; Yan et al., 2011; Zhao et al., 2013). The positive impact of oligosaccharides on bacterial flora and synthesis of short-chain fatty acids in the colon may contribute to changes in protein and lipid metabolism in pigs and thus affect the slaughter value of carcasses and meat quality (Kjos et al., 2010; Krag et al., 2006; Lynch et al., 2007; Yasuda et al., 2006).

Therefore, we hypothesized that the inclusion of inulin extract or chicory and Jerusalem artichoke powder could also benefit growing-finishing pigs by improving their performance and some traits of meat quality.

The reported experiment aimed at determining the effect of the addition of inulin from chicory roots after water or water-alcohol extraction, and powder from Jerusalem artichoke and chicory on production effects as well as slaughter value of carcasses and quality of pork.

Material and methods

All procedures used in this experiment were approved by the responsible Ethics Committee for Experiments on Animals.

The experiment was conducted with 120 weaners, hybrids of (PLW × PL) × Duroc breeds with the initial body weight of 30.0±0.5 kg, which were divided into 5 feeding groups (Table 1). The animals were kept in pens (4 pigs per pen) and fed grower (30–70 kg) and finisher (71–115 kg) diets. The diets contained: cereal meal (wheat and barley), extracted soybean meal, mineral feeds (monocalcium phosphate and ground limestone) and mineral-vitamin premix. The inulin content in diets II–IV was similar. The feed mixtures were balanced in terms of metabolizable energy, total protein, fatty acids digested till the end of the small intestine, as well as minerals and vitamins (Grela et al., 2009). Feed mixtures for each group during the grower and finisher period were isoproteic and isoenergetic. Basic nutrients was determined by AOAC (2000) procedures, and inulin content according to the modified Stahl and Schild (1981) method. The animals had free access to drinkers and feeders (*ad libitum* feeding). Animal husbandry conditions, i.e. temperature, relative humidity and cooling were identical for all groups.

Table 1. Experimental design (g kg^{-1})

Feed	Feeding groups				
	I	II	III	IV	V
Corn starch	40.0	20.0	20.0	-	-
Inulin (water extraction)[1]	-	20.0	-	-	-
Inulin (water-alcohol extraction)[2]	-	-	20.0	-	-
Jerusalem artichoke (*Helianthus tuberosus*)[3]	-	-	-	40.0	-
Chicory (*Cichorium intybus var. sativum*)[4]	-	-	-	-	40.0

[1] Content: inulin (~92%), glucose/fructose/sucrose (~8%).
[2] Content: inulin (~89%), glucose/fructose/sucrose (~8%), other sugar (~1%), polyphenols (~2%).
[3] Content: inulin (49%).
[4] Content: inulin (52%).

The animals were weighed at the beginning of the experiment, then at 2-week intervals and before slaughter. Feed intake was controlled individually by weighing out portions of feed into automatic feeders in particular pens, and calculated for a 2-week period. The fatteners were slaughtered and their right carcasses were subjected to shortened slaughter analysis with the standard SKURTCh method (Różycki and Tyra, 2010). Analyses were performed for physicochemical properties of loin eye area, namely in the samples of *longissimus* muscle from the lumbar section (*m. longissimus lumborum*). Muscle samples were subjected to measurements of: pH_1 after 45 minutes and pH_2 at 24 hours after slaughter; specific electrical conductivity (EC) with a PQM I-Kombi apparatus; and colour analysis according to CIE L*a*b* system (CIE, 1976) using Minolta CR-310 apparatus. Water binding capacity (WBC) was determined according to Grau and Hamm (1952). Drip loss was determined in per cent based on the difference between the weight of muscle sample (packed in a plastic bag) before and after 60-minute heat treatment in a water bath at 70°C. Analyses of the thermally-treated meat samples (after determination of drip loss) included measurements of colour (CIE L*a*b* system) and texture parameters. A shear force test was performed with the use of ZwickRoell B0.5 testing machine in order to determine the maximal shear force and energy, and texture profile analysis (TPA) was made to determine hardness, elasticity, gumminess and chewiness of meat samples. Cylindrical samples (20 × 25 mm) were subjected to double compression to half their initial height using TA.XT.plus texture analyser equipped in a P/10 attachment and an HDP/90 platform. Head speed was 10 mm/min. The shear force was measured using a Warner-Bratzler type shear blade. The maximum shear force was read out at crosshead speed of 50 mm/min. Analyses were conducted on cubicoid samples (20 × 20 mm in cross-section). The samples were cut crosswise. Each measurement was conducted in three replications, and results were presented as mean values from these replications.

Results were subjected to a statistical analysis using Statistica software (2003). Mean value and standard deviation were computed for all analysed variables. One-way (dose) analysis of variance ANOVA was conducted and the significance of differences between mean values was determined with Duncan's test at significance levels of $P \leq 0.05$ and $P \leq 0.01$.

Results

The fattening of animals to ca. 115 kg body weight lasted 98 days (Table 2). The highest daily body weight gains (870–871 g) were obtained by fatteners from groups II and IV with dietary inclusion of the water inulin extract or Jerusalem artichoke powder, respectively (Figure 1), and differences observed between these groups and control group (I) and group V (chicory root powder) were statistically significant (Table 2).

Table 2. Body weight, ADG, FI and FCR of growing-finishing pigs

Item	Groups					SEM	P-value
	I	II	III	IV	V		
Initial body weight (kg)	30.5	29.9	30.8	30.0	30.4	0.188	0.055
Final body weight (kg)	113.1 b	115.6 a	115.2 ab	115.6 a	113.9 b	0.241	0.018
Fattening days	98	98	98	98	98	-	-
Daily weight gains (ADG) (g)							
growing period	817 a	845 b	821 ab	851 b	821 ab	48.7	0.016
finishing period	872	895	892	890	880	39.6	0.086
whole period	843 b	870 a	857 ab	871 a	848 b	38.8	0.022
Feed intake (FI) (kg)							
growing period	1.97	2.00	1.96	1.99	1.99	0.019	0.305
finishing period	2.54	2.52	2.53	2.51	2.55	0.024	0.781
whole period	2.30	2.30	2.29	2.28	2.31	0.029	0.699
Feed conversion ratio (FCR) (kg kg^{-1})							
growing period	2.42	2.39	2.40	2.34	2.42	0.038	0.757
finishing period	2.92	2.82	2.83	2.81	2.92	0.029	0.528
whole period	2.70	2.64	2.64	2.61	2.71	0.030	0.509

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

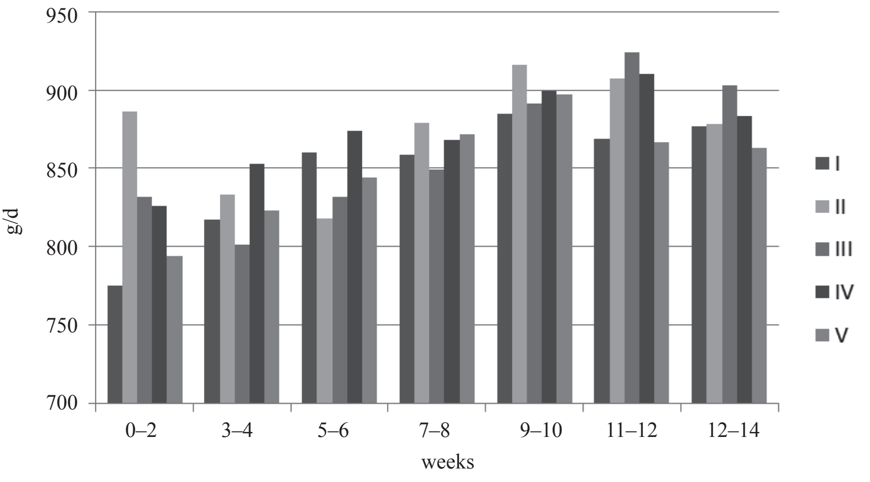


Figure 1. Fortnightly average daily gains in particular groups of fatteners

Feed intake of particular fatteners in fortnights (Figure 2) and in the entire fattening period (Table 2) was similar in particular groups and ranged from 2.28 to 2.31 kg daily. The lowest feed conversion ratio was determined in fatteners from group IV, however a statistically significant difference was noted only at the beginning of fattening between group II and control group (Figure 3). The slaughter analysis of carcasses (Table 3) showed higher meatiness of fatteners from groups IV and V. Differences in meat content of ham and average backfat thickness between these groups and the control group turned out to be statistically significant. In contrast, no significant differences were noted in the weight of kidneys and liver, which indicates that the applied additives had no negative effect on the weight as well as metabolism of these organs.

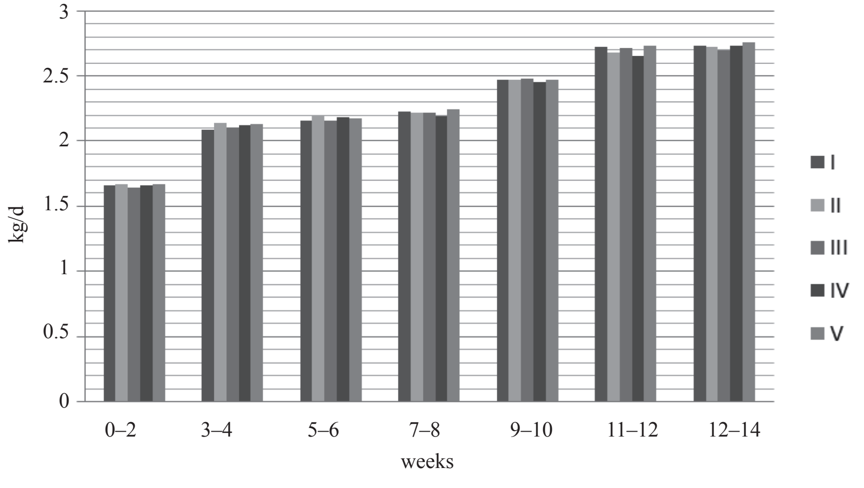
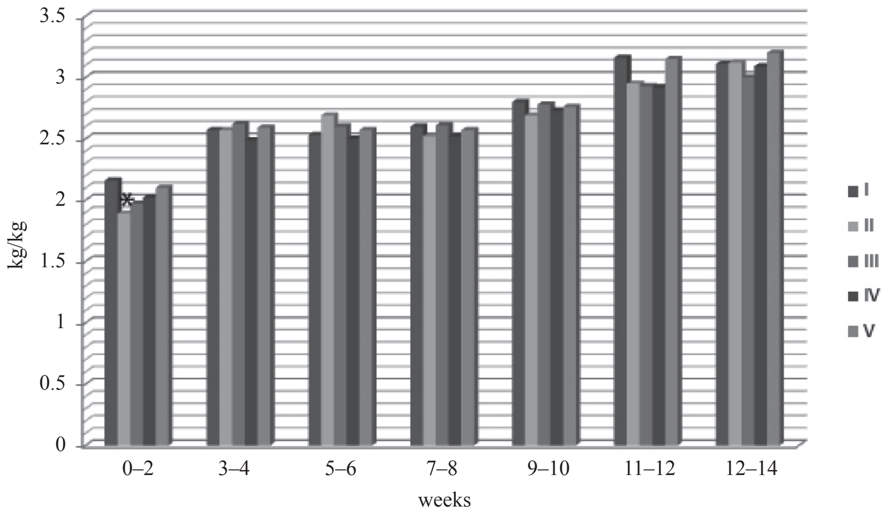


Figure 2. Fortnightly feed intake in particular groups of fatteners



*Values are significantly different in comparison with control group for a given period of time (P≤0.01).

Figure 3. Fortnightly feed conversion ratio in particular groups of fatteners

Table 3. Carcass quality traits and weight of kidneys and livers of fatteners

Item	Groups					SEM	P-value
	I	II	III	IV	V		
Cold dressing yield (%)	78.6	77.9	78.1	77.5	77.8	0.157	0.095
Meat of ham (%)	78.8 b	79.2 ab	79.3 ab	80.5 a	80.7 a	0.195	0.043
Loin eye area (cm^2)	52.4	52.5	52.4	52.8	52.6	0.487	0.114
Meatiness of carcass (%)	55.4	55.7	55.6	56.3	56.4	0.215	0.142
Backfat thickness (cm)							
shoulder	3.20 a	3.17 a	3.02 b	3.10 ab	3.18 a	0.014	0.042
midback	1.71 a	1.77 a	1.65 ab	1.60 b	1.57 b	0.012	0.039
rump I	1.83 a	1.70 ab	1.68 ab	1.55 b	1.62 b	0.013	0.028
rump II	1.33 ab	1.43 a	1.35 ab	1.25 b	1.26 b	0.014	0.041
rump III	1.72 a	1.78 a	1.67 ab	1.53 b	1.51 b	0.232	0.021
rump (3 measurements)	1.63 a	1.62 a	1.57 ab	1.44 b	1.46 b	0.225	0.028
average from 5 measurements	1.96 a	1.96 a	1.87 ab	1.81 b	1.83 b	0.198	0.041
Weight of kidney (g)	169.1	173.7	171.7	174.3	173.5	7.234	0.061
Weight of liver (kg)	1.78	1.73	1.69	1.83	1.74	0.126	0.056

a, b, c – values in the same rows with different letters differ significantly (P≤0.05).

Physical and chemical properties of fresh meat are presented in Table 4. No significant differences were observed in pH values measured 45 min and 24 h after slaughter, and in electrical conductivity. Compared to the control group, a significantly higher (10.2%) lightness (L*) of loin was determined for fatteners from group III. This group was also characterized by the lowest redness (a*) and the highest yellowness values (b*). The chroma value (C*) was the lowest ($P \leq 0.05$), and h° value was the highest in that group compared to the other groups of animals. Measurements of meat water holding capacity (WBC) demonstrate significant differences in values of this parameter between control group and groups III, IV and V ($P \leq 0.05$). Differences were also noticed in M/T ratio, where significantly higher values were obtained for meat from groups III and V, compared to meat from the control animals.

Table 4. Meat quality indices of *longissimus* muscle

Item	Groups					SEM	P-value
	I	II	III	IV	V		
pH_1 45 min after slaughter	6.25	6.29	6.23	6.25	6.29	0.07	0.121
pH_2 24 h after slaughter	5.50	5.59	5.53	5.51	5.59	0.04	0.126
Electrical conductivity, mS cm^{-1}	16.8	18.2	17.2	17.1	18.6	0.32	0.136
Meat colour CIE:							
lightness L*	51.83 b	52.00 b	57.10 a	51.15 b	50.68 b	0.86	0.027
redness a*	19.92 a	19.76 a	16.65 b	18.09 ab	20.54 a	0.46	0.041
yellowness b*	1.42 b	1.41 b	2.15 a	1.42 b	1.57 b	0.18	0.024
colour chroma C*	19.97 a	19.78 a	16.80 b	19.02 a	20.56 a	0.45	0.049
hue h°	4.4 ab	3.8 b	5.1 a	3.6 b	3.7 b	0.66	0.031
Water holding capacity:							
G-H (cm^2)	7.94 a	7.66 ab	6.55 b	6.77 b	6.55 b	0.25	0.045
G-H (mg)	75.75 a	72.78 a	61.11 b	63.39 b	61.12 b	2.64	0.048
M/T×100	20.10 b	25.28 ab	30.45 a	27.51 ab	31.39 a	3.68	0.014

a, b – values in the same rows with different letters differ significantly ($P \leq 0.05$).
M/T – filter paper press method, G-H – water holding capacity according to Grau and Hamm.

The analysis of selected traits of loin after heat treatment did not demonstrate any significant differences between the CIE Lab parameters, drip loss, shear energy or springiness (Table 5). Bratzler shear force value was significantly higher for groups II and IV in comparison with groups III and V. Most of TPA parameters were also modified by the supplements applied. The loin of control fatteners was characterized by significantly higher values of hardness and chewiness, compared to the remaining groups ($P \leq 0.01$). Meat of animals from this group had additionally higher values of gumminess compared to meat from groups II and III ($P \leq 0.01$).

Table 5. Meat quality indices of *longissimus* muscle after heat treatment

Item	Groups					SEM	P-value
	I	II	III	IV	V		
Meat colour CIE:							
lightness L*	68.56	69.13	70.45	69.03	69.79	0.46	0.359
redness a*	11.27	11.02	11.12	10.91	11.19	0.15	0.098
yellowness b*	3.63	3.70	3.42	3.81	3.59	0.11	0.113
colour chroma C*	11.84	11.63	11.56	11.56	11.76	0.13	0.096
hue h°	17.7	18.4	16.1	19.2	17.7	0.62	0.013
Drip loss (%)	28.62	28.94	26.93	27.22	26.58	0.37	0.305
Warner-Bratzler test:							
shear force (N)	64.6 ab	69.1 a	53.9 b	72.5 a	54.6 b	3.94	0.161
shear energy (J)	0.24	0.26	0.19	0.23	0.18	0.05	0.021
Texture profile analysis:							
hardness (N)	130.5 A	85.5 B	68.5 B	78.15 B	77.5 B	17.1	0.008
springiness (mm)	0.57	0.54	0.55	0.53	0.54	0.02	0.202
chewiness (N × mm)	23.86 A	14.41 B	17.24 B	14.31 B	15.84 B	6.25	0.006
gumminess (N)	39.75 A	21.73 B	23.51 B	28.09 AB	29.08 AB	5.64	0.009

A, B – values in the same rows with different letters differ significantly ($P \leq 0.01$).

Discussion

Investigations conducted so far have pointed to a significant impact of inulin on the blood lipid profile (Williams and Jackson, 2002) and to its beneficial effect on the composition of volatile fatty acids in the colon of pigs (Loh et al., 2006; Samanta et al., 2013). Similar effects regarding the beneficial effect of inulin on body weight gains were reported by other authors (Frantz et al., 2003; Kjos et al., 2010; Ponnampalam et al., 2009; Zhao et al., 2013). In the present study, however, analyses demonstrated no effect of the applied additives on FCR. This is in accordance with observations made by Wang and Weishan (2005) who applied 0.3% addition of inulin, and those made by Vhile et al. (2012) who used 4.1%, 8.1%, 12.2% of dried Jerusalem artichoke (containing 50.6% of inulin-type fructans). In turn, a 5% addition of inulin (Ponnampalam et al., 2009) or 7.5 and 15% addition of chicory root powder (Maribo et al., 2010) were shown to improve the FCR. Daily body weight gains were also higher, but statistically significant ($P \leq 0.05$) only in the group of animals administered feed mixture with 15% inclusion of chicory powder. The improvement of production effects in the groups with dietary inclusion of fructans may be explained as resulting from the prebiotic effect of inulin on bacterial flora of the gastrointestinal tract via VFA synthesis (Loh et al., 2006; Samanta et al., 2013). Nonetheless, these effects depend not only on the level of inulin but also on the type of inulin-producing materials, which apart from fructans also contain other biologically-active components: flavonoids, dietary fibre fractions, etc. (Hedemann and Knudsen, 2010; Kjos et al., 2010; Milala et al., 2009). It is likely that these components, apart from inulin (Milala et al., 2009), increased meat content in the ham of fatteners from group IV (chicory powder) and group V (Jerusalem artichoke powder), and decreased fat content of carcass.

Trends for increased colour lightness were also noted by Zhao et al. (2013). The applied additives had no effect on pH value (measured both 45 min and 24 h after slaughter), which is consistent with the findings of other authors (Hansen et al., 2008; Ponnampalam et al., 2009; Zhao et al., 2013). According to Hansen et al. (2008), 10–13.3% addition of dried chicory roots to feed mixture for fatteners slaughtered at 90 kg caused an insignificant increase in L* value of meat and a decrease in drip loss as well as significantly reduced levels of skatole and indole in blood serum. The study conducted by Ponnampalam et al. (2009) showed no significant effect of adding 5% inulin on colour saturation and pH value compared to the control group.

Inclusion of 2% inulin with differing polymerization degrees (water or water-alcohol extraction) or inulin-producing materials (topinambur or chicory roots powder) in fattener mixtures is likely to improve animal performance, but the application of topinambur powder appears to be more justified.

References

Bernet M.F., Brassart D., Neeser J.R., Servin A.L. (1993). Adhesion of human bifidobacterial strains to cultured human intestinal epithelial cells and inhibition of enteropathogen-cell interactions. Appl. Environ. Microbiol., 59: 4121–4128.

CIE (1976). Colorimetry. 2nd ed. Commission Internationale de l'Eclairage, Vienna.

Coumssement P. (1999). Inulin and oligofructose: safe intakes and legal status. J. Nutr., 129: 1412–1417.

Dugan M.E.R., Aalhus J.L., Uttaro B. (2004). Nutritional manipulation of pork quality: current opportunities. Advances in Pork Prod., 15: 237–243.

Flickinger E.A., Van Loo J., Fahey G.C. Jr. (2003). Nutritional responses to the presence of inulin and oligofructose in the diets of domesticated animals: A review. Crit. Rev. Food Sci. Nutr., 4: 19–60.

Frantz N.Z., Nelssen J.L., DeRouchey J.M.,Goodband R.D. (2003). Effects of a prebiotic, inulin, and a direct feed microbial on growth performance of weanling pigs. Swine Day 2003. Kansas State University.

Grau R., Hamm R. (1952). Eine einfache Methode zur Bestimmung der Wasserbindung in Fleisch. Fleischwirtschaft, 4: 295–297.

Grela E.R. (2006). Withdrawal of antibiotic growth promoters from pig nutrition – effects and future. Pol. J. Nat. Sci., Suppl. 3, 1: 15–22.

Grela E.R., Pastuszak J., Bloch U. (2009). Handbook of modern pig feeding. Recommendation for practice (in Polish). SRRiL Progress, Lublin.

Hansen L.L., Stolzenbach S., Jensen J.A., Henckel P., Hansen-Møller J., Syriopoulos K., Byrne D.V. (2008). Effect of feeding fermentable fibre-rich feedstuffs on meat quality with emphasis on chemical and sensory boar taint in entire male and female pigs. Meat Sci., 80: 1165–1173.

Hedemann M.S., Knudsen K.E.B. (2010). Dried chicory root has minor effects on the digestibility of nutrients and the composition of the microflora at the terminal ileum and in faeces of growing pigs. Livest. Sci., 134: 53–55.

Kjos N.P., Øverland M., Fauske A.K., Sørum H. (2010). Feeding chicory inulin to entire male pigs during the last period before slaughter reduces skatole in digesta and backfat. Livest. Sci., 134: 143–145.

Krag L., Thomsen L.E., Iburg T. (2006). Pathology of *Trichuris suis* infection in pigs fed an inulin- and a non-inulin-containing diet. J. Vet. Med. Physiol. Pathol. Clin. Med., 53: 405–409.

Loh G., Eberhard M., Brunner R.M., Hennig U., Kuhla S., Kleessen B., Metges C.C. (2006). Inulin alters the intestinal microbiota and short-chain fatty acid concentrations in growing pigs regardless of their basal diet. J. Nutr., 136: 1198–1202.

Lynch M.B., Sweeney T., Callan J.J., O'Doherty J.V. (2007). The effect of dietary crude protein concentration and inulin supplementation on nitrogen excretion and intestinal microflora from finisher pigs. Livest. Sci., 109: 204–207.

Maribo H., Johansen M. (2010). Chicory for weaners. Pig Research Centre, Danish Agriculture & Food Council. Trial report 870.

McCracken V.J., Gaskins H.R. (1999). Probiotics and the immune system. In: Probiotics: a critical review, Tannock G.W. (ed.). Wymondham. Horizon Scientific Press., pp. 85–111.

Milala J., Grzelak K., Król B., Juśkiewicz J., Zduńczyk Z. (2009). Composition and properties of chicory extracts rich in fructans and polyphenols. Pol. J. Food Nutr. Sci., 59: 35–43.

Playne M.J., Crittenden R. (1996). Commercially available oligosaccharides. Bull. Int. Dairy J., 313: 10–22.

Ponnampalam E., Jayasooriya D., Gill H., Pluske J., Dunshea F. (2009). Nutritional manipulation of iron level in finisher pigs and fresh pork. Final Report (3A-108) prepared for the Co-operative Research Centre for an Internationally Competitive Pork Industry.

Rosenvold K., Andersen H.J. (2003). Factors of significance for pork quality – a review. Meat Sci., 64: 219–237.

Różycki M., Tyra M. (2010). Methodology for fattening and slaughter value at Pig Testing Station (SKURTCh) (in Polish). Wyd. wł. IZ, Kraków, 28: 94–105.

Samanta A.K., Jayapal N., Senani S., Kolte A.P., Sridhar M. (2013). Prebiotic inulin: Useful dietary adjuncts to manipulate the livestock gut microflora. Braz. J. Microbiol. 44: 1–14.

Van Loo J. (2007). How chicory fructans contribute to zootechnical performance and well-being in livestock and companion animals. J. Nutr., 137: 2594–2597.

Vhile S.G., Kjos N.P., Sørum H., Overland M. (2012). Feeding Jerusalem artichoke reduced skatole level and changed intestinal microbiota in the gut of entire male pigs. Animal, 6: 807–814.

Weishan W. (2005). Effect of inulin and fermented feed additive on growth and nitrogen balance in pig. Masters thesis, Universiti Putra, Malaysia.

Williams C.M., Jackson K.G. (2002). Inulin and oligofructose: effects on lipid metabolism from human studies. Br. J. Nutr., 87: 261–264.

Yan L., Meng O.W., Kim L.H. (2011). The effects of dietary *Houttuynia cordata* and *Taraxacum officinale* extract powder on growth performance, nutrient digestibility, blood characteristics and meat quality in finishing pigs. Livest. Sci., 141: 188–193.

Yasuda K., Ronecker K.R., Miller D., Welch R.M., Lei X.G. (2006). Supplemental dietary inulin affects the bioavailability of iron in corn and soybean meal to young pigs. J. Nutr., 136: 3033–3038.

Zhao P.Y., Wang J.P., Kim I.H. (2013). Evaluation of dietary fructan supplementation on growth performance, nutrient digestibility, meat quality, fecal microbial flora, and fecal noxious gas emission in finishing pigs. J. Anim. Sci., 91: 5280–5286.

Received: 13 I 2014
Accepted: 16 IV 2014