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Production value and cost-effectiveness of pig fattening using liquid feeding or enzyme-supplemented dry mixes containing rye grain

T. Schwarz[1], A. Turek[1,2], J. Nowicki[1], R. Tuz[1], B. Rudzki[3], P.M. Bartlewski[4]

[1]Department of Swine and Small Animal Breeding, Institute of Animal Sciences, University of Agriculture in Krakow, Krakow, Poland
[2]Blattin Poland Sp. z o.o., Siedlec, Poland
[3]KWS Lochow Poland Sp. z o.o., Kondratowice, Poland
[4]Department of Biomedical Sciences, Ontario Veterinary College, University of Guelph, Guelph, Canada

ABSTRACT: The aim of this study was to assess the cost-effectiveness of a fermented liquid feeding and enzyme supplementation of dry fodders containing rye grain for pig fattening. Two experiments were performed on 126 gilts (82 in Experiment 1 and 44 in Experiment 2) of hybrid Pig Improvement Company (PIC) lines. In both experiments, the pigs were randomly divided into two equinumeric groups (treatment vs control). In Experiment 1, the treatment group received a diet containing 25% of rye grain (cultivar Visello) in the grower and 50% in the finisher period, replacing a proportion of barley from control mixes, and the fodders were given as pre-fermented liquid feed twice daily. In Experiment 2, both the control and experimental diets contained rye grain at the same quantities as the experimental group in Experiment 1, but the mixes for the treatment groups were supplemented with 0.01% of xylanase and fed in dry form. There were no differences in the mean growth rate or feed conversion ratio between the control and experimental groups of gilts. In Experiment 1, there was no effect of rye feeding on backfat thickness, loin depth, and meatiness, and hence the final carcass price, but the overall cost of fattening was lower by 5.1% in rye-fed pigs, which resulted in an 11.3% surplus. In Experiment 2, the backfat thickness was significantly greater and the lean meat content lower in the experimental compared with control group of animals. In spite of these differences, the lower cost of feeding (by 3.4%) resulted in a 5.2% increment in the economic efficiency of production of pigs receiving enzyme-supplemented mixes. It can be concluded that, in comparison to traditional barley-based nutrition, the pig fattening utilizing rye grain in wet fermented mixes is more profitable. The increased bottom-line profits of using dry rye mixes with carbohydrate-hydrolyzing enzymes appear to be associated with declining carcass quality.

Keywords: swine; barley; fattener; enzyme; yeast; xylanase

INTRODUCTION

Swine producers are reluctant to extensively use rye grain due mainly to its high content of anti-nutrients, which lessen the production efficiency of animals receiving large quantities of rye in their diets (Sullivan et al. 2005). Over the past several years, however, a number of new rye varieties with significantly reduced content of anti-nutritive substances have become available on the market (Makarska et al. 2007; Jurgens et al. 2012). Many of these new varieties have been tested as the primary feed ingredient (≥ 50% of total feed content) for fattener pigs in commercial operations (Hooper et al. 2002; Schwarz et al. 2015). In a recent study, we assessed and compared the fattening and slaughter parameters of pigs that had received dry mixes prepared with barley or Visello rye grain as the main raw component

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(Schwarz et al. 2015). This rye variety is characterized by a reduced concentration and activity of all major anti-nutrients (i.e. alkylresorcinols, pentosans, and tripsin inhibitors), and is also highly resistant to ergot contamination due to the application of the POLLENPLUS® technology (www.kws-lochow.pl/odmiany/wszystkie-odmiany/zboze/zyto/odmiana/visello.html). The use of Visello cultivar was associated with greater weight gains and improved carcass quality (EUROP classification system) of fattener pigs in comparison to traditional barley-containing dry mixes, albeit the feed conversion ratio (FCR) of rye was still less compared with that of barley, increasing the overall cost of feeding (Schwarz et al. 2015).

Initially, the alkylresorcinols were considered the most important ingredients limiting rye digestibility and hence its usefulness in animal nutrition (Sedlet et al. 1984). In the 1980s, several modern rye cultivars with significantly reduced alkylresorcinol concentrations had been developed (Hoffmann and Wenzel 1981), but despite these technological advancements, a number of studies still have shown suboptimal productivity in commercial herds of pigs receiving large quantities of the rye cultivars (Makarska et al. 2007; Jurgens et al. 2012). Therefore, in the early1990s, the importance of alkylresorcinols as a primary anti-nutrient was questioned, and more attention was devoted to other substances present in rye grain.

An intrinsic anti-trypsin activity of rye is severalfold higher compared to that of barley and wheat grains; however, a study using autoclaving of rye grain to eliminate the activity of proteolytic enzyme inhibitors showed no effect of such a treatment on rye digestibility (Sosulski et al. 1988). Extensive genetic selection has resulted in substantial lowering of the anti-trypsin activity of several modern rye varieties (Makarska et al. 2007); even though it remained higher than in other cereal grains, its content was lower than in the primary source of protein – the soybean meal (Kim and Baker 2003; Schwarz et al. 2015). Nevertheless, the use of new rye cultivars with reduced anti-trypsin activity for pig fattening was still associated with suboptimal or variable results.

At present, the non-starch polysaccharides (NSPs) are thought to be the main constituent decreasing nutritional value of rye in high-output livestock production systems (Boros et al. 1993). Although NSPs can be found in all types of cereal grain, rye has the highest concentration of pentosans characterized by high rates of water absorption and swelling, which ultimately leads to a feeling of fullness and limits voluntary food intake (Misir and Marquardt 1978). In addition, dietary pentosans, mainly arabinoxilans, form highly viscous solutions, which significantly reduce the absorption and utilization of nutrients from chyme (Boros et al. 1993; Im et al. 1999; Thacker et al. 1999; 2002).

The most frequently used approach to improving the FCR in growing pigs is the use of liquid feed fermented with yeast (de Lange et al. 2006). The fermentation process induced by yeast enzymes boosts the digestibility of nearly all feed components including fibre and NSPs (Wenk 2000; Brooks et al. 2001). An additional advantage of using wet yeast-containing mixes is the improved gut health of pigs owing to the acidifying and probiotic effects of pre-fermented food (van Winsen et al. 2001). Liquid nutrition of fattener pigs is rapidly gaining popularity in Europe, the USA, and Canada since it permits the use of relatively inexpensive byproducts such as soluble grain distillers, liquid whey, buttermilk, brewers' wet yeast or barley sprouts (de Lange et al. 2006). These products are protein-rich and so cereal grains remain the main source of metabolic energy in liquid nutrition (de Lange et al. 2006). High moisture corn has been used as a cheap and efficient energy source (Niven et al. 2007); however, the use of large quantities of corn in grower and finisher pigs can impinge negatively on the quality of pork meat and fat (Lampe et al. 2006; Benz et al. 2011). The replacement of corn with other cereal grains may be beneficial to pork quality, but would greatly increase the cost of fattening especially if more expensive grain such as wheat or barley was used. Therefore, the less expensive yet equally effective energy sources (e.g. a mix of rye and barley) would be a desirable alternative in liquid nutrition of fattener pigs.

Another method employed to increase the digestibility of dietary NSPs in pigs is the addition of enzymes such as xylanase (mainly used with wheat, triticale, and rye) or glucanase (developed for barley) (Johnson et al. 1993; Hanczakowska and Koczywas 2008). However, the results of studies using rye fodder mixtures containing xylanase in growing pigs are ambiguous, and substantial improvements in rye digestibility are not consistently seen (Thacker et al. 1992, 1999). One possible explanation of such results could be the use of older

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varieties of rye and the potential impact of other anti-nutrients they contain (e.g., trypsin inhibitors) on overall food digestibility, because similar studies utilizing other cereals showed significant improvement in terms of food utilization and growth rates of pigs (Omogbenigun et al. 2004).

Therefore, the major goal of the present study was to evaluate the production value and economic efficiency of using the fermented liquid feed or xylanase supplementation of dry fodder mixes containing a modern rye cultivar Visello in a two-phase pig fattening regimen in commercial settings.

MATERIAL AND METHODS

Animals and experimental procedures. All experimental procedures performed on live animals were in compliance with the EU Directive 2010/63/EU for animal experiments and the Polish law for the care and use of animals (August 2, 1997), and had been approved by the local Animal Care and Ethics in Research Committee. The present study was carried out as two separate experiments performed at two commercial farms, one located in Drzęczewo, in Wielkopolska Province in central-western Poland, and the second located in Pilczyca, in Świętokrzyskie Province in central Poland. Both experiments were carried out from mid-April until the end of July/beginning of August.

Experiment 1. The first experiment utilized 82 hybrid gilts (offspring of Camborough line 22 sows × 337 line boars; Pig Improvement Company (PIC), Warsaw, Poland). The mean (± SD) body weight of piglets at the outset of the study was 25.3 ± 3.8 kg. The animals were randomly divided into two equal groups (control and experimental, $n = 41$ each) that were housed in two separate pens for the entire duration of the present study.

There were two phases (grower and finisher) of fattening with fodder mixes prepared according to the German DLG standards (DLG 2011). The mixes were supplemented with a special premix for PIC pigs and fermenting yeast (Blattin Poland, Schodnia, Poland), and then mixed with water (water to feed ratio of 2.2 : 1 as per manufacturer's recommendation). Dry fodders were mixed with water (35°C) approximately 10 h prior to feeding to enable activation of yeast enzymes and sufficient yeast and bacterial fermentation. Experimental diets contained 25% and 50% of Visello rye grain in the grower and finisher phase, respectively, replacing a proportion of barley grain that was the principal ingredient in control diets (Table 1). Animals were fed twice daily at 6:00 and 18:00, and had unrestricted access to water through sucking troughs. The fattening period lasted 116 days (68 and 48 days for the grower and finisher phases, respectively).

Experiment 2. The second experiment utilized 44 hybrid gilts (offspring of Camborough line 22 sows × 337 line boars; Pig Improvement Company (PIC), Warsaw, Poland). The mean body weight of the purchased piglets was 30.0 ± 3.1 kg. The animals were randomly divided into two equal groups ($n = 22$ each), the control group and the experimental group, and placed in the group pens of 5–6 animals (4 pens per group).

The source and preparation of dry mixes were the same as in Experiment 1 above. The entire fattening period (105 days) consisted of the grower and finisher phases (64 and 41 days for the grower and finisher phase, respectively). The experimental feedstuff mixes were supplemented with 0.01% of 1,4-beta-xylanase (Danisco Xylanase 40000G; Noack & Co. GmbH, Vienna, Austria). An estimated enzymatic activity of the supplement was 40 000 U/g, giving the final activity of 4000 U/kg of complete feedstuff, as recommended by the European Food Safety Authority regulations (EFSA 2011). Pigs were fed *ad libitum* using Domino feeders (Domino Co., Tørring, Denmark) and had unrestricted access to fresh water.

Laboratory analyses. In both experiments, the feed content of essential nutrients was determined using the Fourier Transform-Near Infrared (FT-NIR) spectroscopy. Each forage sample was exposed to electromagnetic radiation in the near-infrared range that is absorbed by a sample and causes vibrations of the chemical bonds. These vibrations alter the output signal reaching the detector and it contains readable information about the chemical composition of the sample. The built-in software analyzes points that are specific to individual chemical bonds and identifies individual compounds with high accuracy. Then, the sample spectra are compared with a mathematical model created during the calibration of the device to determine the qualitative and quantitative chemical composition of the sample.

Assessment of productive performance, carcass quality, and prices. The live weight of all animals was taken at the beginning of the experiment and

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Table 1. Chemical composition of the liquid (L), grower (G) and finisher (F) mixes in the control (C) and experimental (E) groups of fattener pigs, and of the dry (D) mixes with or without enzyme supplementation

Ingredients (%)	Experiment 1[1]				Experiment 2[2]	
	LGC	LGE	LFC	LFE	DG	DF
Soybean meal	15.0	16.0	7.0	9.0	18.7	7.0
Rape grain meal	–	–	–	–	–	4.0
Wheat	34.0	32.0	21.0	15.0	9.0	25.0
Barley	35.0	10.0	57.0	5.0	15.0	11.5
Rye	–	25.0	–	50.0	25.0	50.0
Malt sprouts	2.0	3.0	1.5	2.5	–	–
Barley tailings	10.0	10.0	15.0	15.0	–	–
Soybean oil	–	–	–	–	1.0	–
Yeast	0.5	0.5	0.5	0.5	–	–
Acid	0.2	0.2	–	–	0.3	–
Glucose	0.3	0.3	0.2	0.2	–	–
Minerals/vitamins	3.0	3.0	2.8	2.8	3.0	2.5
Dry matter	87.5	87.9	87.4	88.2	87.4	87.3
Ash	5.7	5.6	5.6	5.0	5.7	5.0
Crude protein	17.7	17.7	15.1	14.8	17.4	14.0
Fat	1.8	1.7	1.8	1.6	2.6	1.6
Starch	43.1	42.2	45.9	45.5	41.0	45.4
Monosaccharides	3.9	5.0	3.1	5.1	4.7	4.8
Fibre	4.3	3.4	4.9	3.2	2.9	3.2
Ca (g/kg)	7.5	7.7	7.4	6.9	7.7	6.7
P (g/kg)	5.4	5.3	5.2	4.8	5.1	5.0
Lysine	1.0	1.1	0.8	0.8	1.1	0.8
Methionine + cysteine	0.6	0.6	0.5	0.6	0.7	0.6
Threonine	0.7	0.7	0.5	0.6	0.7	0.5
Tryptophan	0.2	0.2	0.2	0.2	0.2	0.2
Metabolizable energy (MJ/kg)	13.0	13.1	13.0	13.0	13.3	12.9

[1]Experiment 1: treatment group received a diet containing 25% of rye grain (cultivar Visello) in the grower and 50% in the finisher, replacing a proportion of barley from control mixes

[2]Experiment 2: both the control and experimental diets contained rye grain at the same quantities as the treatment group in Experiment 1, but the mixes for experimental animals were supplemented with 0.01% xylanase

after each phase of fattening as well as just before slaughter. After 116 or 105 days of fattening (Experiment 1 and 2, respectively), pigs were sold to a local abattoir. The carcasses were weighed after the pigs had been exsanguinated and eviscerated. The lean meat content was assessed using an Ultra-Fom 300 apparatus (Carometec Denmark, Herlev, Denmark) validated for commercial use in pigs. Subsequently, the carcasses were assessed using the EUROP standard system and appraised according to current market prices. The EUROP system for carcasses comprises six different classes, varying in the lean meat content (LMC) by ~5%, from Class S (> 60% LMC) to Class P (< 40% LMC). The price of 1 kg of carcass for different classes in Experiment 1 was as follows: S class – 6.68 PLN; E class – 6.44 PLN; U class – 6.12 PLN; and R class – 5.28 PLN. In Experiment 2, all carcasses were classified into either S or E classes, and the price of 1 kg of carcasses was 6.90 PLN or 6.80 PLN, respectively. All cost-related variables analyzed in this study had initially been calculated in PLN, but were subsequently converted to $US to provide a clearer comparison to international readers.

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Statistical analyses. The measures of fattening efficiency included feed intake per pen, feed conversion per 1 kg of growth (per pen), and daily weight gains (individually) during the grower and finisher phases separately and for the entire experimental period. Pre- and post-slaughter assessments included live weight, carcass weight, dressing percentage, backfat thickness, loin depth, meatiness, and percentage of carcasses in different classes of EUROP system. The final analysis included the following economic indicators: production cost of 1 kg of body weight gain, price of 1 kg of carcass, whole carcass price, total sale values, total cost of the purchase of piglets, total cost of feedstuff for fattening, and the direct surplus of production. All fattening, slaughter, and economic parameters were compared between control and experimental groups using Student's *t*-test and proportions were analyzed by χ^2-square test (Brendt and Snedecor formula). Statistical significance was set at $P < 0.05$. All results are expressed as mean ± SD unless otherwise indicated.

RESULTS

The chemical composition and metabolic energy values for compound diets used in the present experiments are given in Table 1. Both the control and experimental diets were prepared to contain similar concentrations of all basic ingredients (isocaloric and isonitrgenous).

The overall and daily weight gains per pig were higher ($P < 0.01$) in finisher gilts receiving rye-containing wet mixes but the daily weight gains were lower ($P < 0.05$) in grower pigs fed rye-based feedstuff supplemented with 0.01% xylanase (Table 2). Only numerical ($P > 0.05$) differences were seen in the mean feed intakes and feed to gain ratio between experimental and control groups of animals in both experiments (Table 3). In Experiment 1, the slaughter value was lower ($P < 0.01$) in the experimental group of fattener pigs (Table 4). The mean backfat thickness was higher ($P < 0.01$) and the loin eye depth was lower ($P < 0.01$) in the experimental as compared to control group in Experiment 2. As a result, the carcasses of experimental gilts had lower ($P < 0.01$) lean meat content. In terms of the EUROP system classification, all carcasses in Experiment 2 were categorized as S class or E class. Control animals exceeded the experimental group in the proportion of S class carcasses ($P < 0.01$) but a significantly greater percentage of E class carcasses was observed in the experimental group that had received enzyme-supplemented rye-based diets. The carcass price per unit of weight was lower ($P < 0.01$) in the experimental group compared with controls.

In Experiment 1, all of the economic parameters analyzed showed a decreasing trend in animals fed rye-containing wet mixes, indicating better overall economic effects/lower production costs in the experimental group of pigs (Table 5). In Experiment 2, there was a decline in 8 out of 11 economic

Table 2. Body weight and weight gains in the control (C) and experimental (E) groups of fattener pigs receiving pre-fermented liquid feed (L) or dry mixes (D). Durations of the fattening phases are given in parentheses

Variables	Experiment 1		Experiment 2	
	LC	LE	DC	DE
Live weights (kg)				
Initial body weight	25.1 ± 3.6	25.4 ± 4.1	29.7 ± 3.4	30.3 ± 2.9
Body weight after grower phase	77.9 ± 9.1	79.3 ± 9.8	79.5 ± 4.7	78.6 ± 4.1
Body weight before slaughtering	112.4 ± 11.0	116.4 ± 14.2	109.3 ± 10.2	108.8 ± 5.6
Weight gain/pig (kg)				
Grower phase (68 days/64 days)	52.8 ± 7.3	53.9 ± 7.7	49.7 ± 2.4	47.7 ± 3.2
Finisher phase (48 days/41 days)	34.5 ± 3.5^{A}	37.1 ± 5.8^{B}	29.8 ± 6.1	30.9 ± 4.4
Whole fattening period (116 days/105 days)	87.2 ± 9.1	91.0 ± 12.2	79.5 ± 7.4	78.6 ± 3.6
Daily weight gain (g)				
Grower phase	776 ± 107	792 ± 113	776 ± 37^{c}	745 ± 56^{d}
Finisher phase	718 ± 74^{A}	773 ± 121^{B}	727 ± 149	753 ± 119
Whole fattening period	752 ± 78	784 ± 105	758 ± 70	748 ± 38

within rows, means denoted by different superscripts differ: $^{AB}P < 0.01$ (Experiment 1), $^{cd}P < 0.05$ (Experiment 2)

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Table 3. Average feed intake and conversion rates in pigs during the two-phase fattening period with pre-fermented liquid feed (L) or dry mixes (D) in the control (C) and experimental (E) groups of fattener pigs. Durations of the fattening phases are given in parentheses

Variables	Experiment 1		Experiment 2	
	LC	LE	DC	DE
Net feed intake during fattening phases (kg)				
Grower phase (68 days/64 days)	6 355	6 191	3 220	3 080
Finisher phase (48 days/41 days)	4 380	4 381	1 876	1 809
Whole fattening period (116 days/105 days)	10 735	10 572	5 096	4 889
Feed intake per pig per fattening phase (kg)				
Grower phase	151.3	147.4	146.4 ± 5.2	140.0 ± 3.5
Finisher phase	106.8	106.9	85.3 ± 7.1	82.2 ± 5.4
Whole fattening period	255.6	251.7	231.6 ± 6.6	222.2 ± 5.0
Daily feed intake per pig (kg)				
Grower phase	2.2	2.2	2.3 ± 0.2	2.2 ± 0.2
Finisher phase	2.2	2.2	2.1 ± 0.2	2.0 ± 0.2
Whole fattening period	2.2	2.2	2.2 ± 0.2	2.1 ± 0.2
Feed to gain ratio (kg)				
Grower phase	2.9	2.8	2.9 ± 0.2	2.9 ± 0.1
Finisher phase	3.1	2.9	2.9 ± 0.1	2.7 ± 0.1
Whole fattening period	3.0	2.8	2.9 ± 0.2	2.8 ± 0.1

parameters in the group receiving enzyme-supplemented dry mixes compared with their respective controls, but the grower and finisher mix prices as well as the cost of 1 kg weight gain in grower pigs increased in the experimental group. In all, an 11.3% increase in the profitability of production in pigs receiving rye-based liquid fermented diets and a 5.2% rise in the profitability of pig fattening using dry mixes with rye and xylanase were noted in the present study (Table 6).

Table 4. Summary of slaughter values, EUROP system classification of carcasses, and mean carcass prices of the control (C) and experimental groups (E) of fattener pigs receiving pre-fermented liquid feed (L) or dry mixes (D)

Variable	Experiment 1		Experiment 2	
	LC	LE	DC	DE
Pre-slaughter live weight (kg)	112.4 ± 11.0	116.4 ± 14.2	109.3 ± 10.2	108.8 ± 5.6
Carcass weight (kg)	93.0 ± 9.2	95.0 ± 11.2	83.1 ± 7.9	83.6 ± 9.0
Slaughter value (%)	82.8 ± 0.6^{A}	81.7 ± 2.0^{B}	76.1 ± 2.0	76.6 ± 4.4
Backfat thickness (mm)	15.6 ± 4.4	16.3 ± 3.3	11.2 ± 2.5^{C}	14.1 ± 3.2^{D}
Loin depth (mm)	60.1 ± 5.3	58.4 ± 5.2	67.1 ± 5.8^{C}	62.2 ± 7.2^{D}
Lean meat content (%)	56.5 ± 4.0	55.5 ± 3.2	61.3 ± 1.7^{C}	58.8 ± 2.5^{D}
% of carcasses in:				
S class	17.1	4.9	81.8^{C}	36.4^{D}
E class	51.2	56.1	18.2^{C}	63.6^{D}
U class	24.4	36.6	–	–
R class	7.3	2.4	–	–
Carcass price/1 kg (PLN/USD)*	6.3 ± 0.4/1.9 ± 0.1	6.3 ± 0.2/1.9 ± 0.1	6.9 ± 0.04/2.2 ± 0.01^{C}	6.8 ± 0.05/2.1 ± 0.02^{D}
Total carcass price (PLN/USD)*	586.8 ± 58.0/ 177.6 ± 17. 6	600.6 ± 67.3/ 181.8 ± 20.4	572.2 ± 53.6/ 178.8 ± 16.8	571.3 ± 60.2/ 178.5 ± 18.8

within rows, means denoted by different superscripts differ: $^{AB}P < 0.01$ (Experiment 1), $^{CD}P < 0.01$ (Experiment 2)

*exchange rate (National Bank of Poland): 1 USD = 3.3040 PLN as of 08/08/2012

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Table 5. Costs of nutrition incurred during pig fattening using barley- or rye-based liquid feeding (LC and LE, respectively) or rye-containing dry mixes with or without 0.01% xylanase (DC and DE, respectively); C denotes control and E denotes experimental groups of fattener pigs

Variables (PLN/USD)**	Experiment 1			Experiment 2		
	LC	LE	% decrease*	DC	DE	% increase or decrease*
Grower mix price	1 018.7/ 308.3	998.4/ 302.2	–2.0	1 164.6/ 363.9	1 172.2/ 366.3	+0.7
Grower phase cost	6 473.5/ 1 959.3	6 180.8/ 1 870.7	–4.5	3 750.0/ 1 171.8	3 610.4/1 128.2	–3.7
Grower phase cost/pig	154.1/46.7	147.2/44.5	–4.5	170.5 ± 2.7/ 53.3 ± 0.8	164.1 ± 4.2/ 51.3 ± 1.3	–3.7
Grower phase cost of 1 kg weight gain	3.0/0.9	2.8/0.9	–6.4	3.43 ± 0.2/ 1.1 ± 0.06	3.4 ± 0.1/ 1.1 ± 0.03	+0.3
Finisher mix price	936.7/ 283.5	880.8/ 266.6	–6.0	1 002.0/ 313.1	1 009.5/ 315.5	+0.8
Finisher phase cost	4 102.8/ 1 241.8	3 858.9/ 1 168.0	–5.9	1 879.8/ 587.4	1 826.3/ 570.7	–2.9
Finisher phase cost/pig	100.1/30.3	94.1/28.5	–6.0	85.4 ± 4.3/ 26.7 ± 1.3	83.0 ± 3.1/ 25.9 ± 8.1	–2.8
Finisher phase cost of 1 kg weight gain	2.9/0.9	2.5/0.8	–12.4	2.9 ± 0.1/ 0.9 ± 0.03	2.7 ± 0.09/ 0.8 ± 0.03	–6.3
Total cost of fattening	10 576.3/ 3 201.1	10 039.7/ 3 038.7	–5.1	5 629.8/ 1 759.3	5 436.6/ 1 698.9	–3.4
Total cost of fattening/pig	254.2/76.9	241.3/73.0	–5.1	255.9 ± 5.2/ 80.0 ± 1.6	247.1 ± 4.2/ 77.2 ± 1.3	–3.4
Total cost of 1 kg weight gain	3.0/0.9	2.7/0.8	-–9.1	3.2 ± 0.1/ 1.0 ± 0.03	3.2 ± 0.09/ 1.0 ± 0.03	–2.2

*percentage increase/decrease in the treatment group relative to the control group
**exchange rate (National Bank of Poland): 1 USD = 3.3040 PLN as of 08/08/2012

DISCUSSION

In evaluating certain end points in Experiment 1, the standard deviations of the mean values could not be calculated for the treatment and control groups, which precluded our being able to perform further statistical comparisons. However, numerical differences between the two groups are still relevant and useful indicators of economic efficiency. Generally, the present results are in

Table 6. Calculation of simplified direct surplus from pig fattening using barley- or rye-based liquid feeding (LC and LE, respectively) or rye-containing dry mixes with or without 0.01% xylanase (DC and DE, respectively); C denotes control and E denotes experimental groups of fattener pigs

Variable (PLN/USD)**	Experiment 1			Experiment 2		
	LC	LE	% increase or decrease*	DC	DE	% increase or decrease*
Total sale value	24 059.6/7 282.0	24 624.9/7 453.1	+2.4	12 587.6/3 930.7	12 568.8/3 927.6	–0.1
Purchase price of piglets	7 629.4/2 309.1	7 710.8/2 333.8	+1.1	5 559.0/1 737.1	5 661.0/1 769.0	+1.8
Total costs of feed	10 576.3/3 201.1	10 039.7/3 038.7	–5.1	5 629.8/1 759.3	5 436.6/1 698.9	–3.4
Grand total (expenditures)	18 205.7/5 510.2	17 750.5/5 372.4	–2.5	11 188.8/3 496.4	11 097.6/3 467.9	–0.8
Simplified direct surplus	5 853.9/1 771.8	6 514.4/1 971.7	+11.3	1 398.8/437.1	1 471.2/459.7	+5.2

*percentage increase in the treatment group relative to the control group
**exchange rate (National Bank of Poland): 1 USD = 3.3040 PLN as of 08/08/2012

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agreement with our earlier observations on the suitability of Visello rye cultivar for pig fattening (Schwarz et al. 2015). The addition of yeast for fermentation of wet fodder ~10 h prior to feeding resulted in lower feed to gain ratios in rye-fed as compared to barley-fed gilts. Nearly all ingredients of pre-fermented liquid feed are more easily digestible to pigs than those contained in dry mixes and that applies to normally indigestible NSPs as well (Kornegay et al. 1995; van Heugten et al. 2003). The significantly greater weight gain and FCR were, at least in part, nullified by worse slaughter parameters in pigs receiving rye-containing liquid feed.

In Experiment 2, dry mixes given to experimental animals were supplemented with xylanase breaking up arabinoxylan bonds. Similarly to the previous findings of Thacker et al. (2002), our present results are rather ambiguous. We did not find statistically significant differences in FCRs between the control and experimental groups of pigs. There were, however, numerical differences between the finisher diets, which may explain a reduction in an overall cost of fattening. Alternatively, a significant reduction in body weight gain was observed in the experimental groups of animals during the grower phase. The assessment of carcass characteristics has clearly shown the increased adiposity and reduced meatiness of carcasses following the feeding with enzyme-supplemented rye-containing mixes. One possible reason for the reduced weight gain in experimental animals is the increased utilization of dietary NSPs. The NSPs are long-chain carbohydrates, practically indigestible, with only a limited impact on the energy balance of the feedstuff mixture. However, xylanases liberate the nutrients from NSPs by reducing their viscosity/depolarizing arabinoxilans, which makes the polysaccharides more easily available for fermentation by the gut microflora. Their subsequent conversion into short chain fatty acids by the intestinal microflora contributes to the energy supply. Thus, in the group of pigs receiving enzyme-supplemented mixes, the energy-to-protein balance of the feed was probably skewed towards the energy. This possible shift, or unbalanced dietary energy boost in Experiment 2, was probably greater than in Experiment 1, resulting not only in an increased deposition of fat and lower lean meat content, but also in the decreased body weight gain (de Greef and Verstegen 1993; deGreef et al. 1994); clearly, the rate of fat deposition was much lower than the increase in muscle mass. Currently, there are no standardized feeding regimens to deal with such situations. In Denmark, an increment in protein concentration by 1% above the standard level is recommended to prevent an apparent protein deficiency in the face of increased energy supply after enzymatically enhanced digestibility of dietary NSPs (S. Hansen, pers. comm.; Rye Belt Animal Nutrition Designer Team Workshop, 27–28 November 2012, Viborg, Denmark). However, this recommendation offered by agricultural consultants in the production practice has yet to be corroborated by the results of laboratory analyses. It is, therefore, of paramount importance to devise an accurate method of determining the increase in metabolic energy of the dry and wet mixes after the use of enzyme supplementation/yeast fermentation, and to develop a set of easy-to-use standards for adjusting the composition of the feeds to restore an optimal protein-to-energy ratio.

In summary, our results showed an overall improvement in both the productive and economic indicators in fattener pigs receiving rye-based mixtures in comparison to pigs fed barley-based diets in the pre-fermented liquid nutrition system. The use of rye-containing mixes supplemented with xylanase in the dry feeding regimen enhanced production profitability slightly (by 2.2%) despite the declining slaughter parameters or desirable carcass characteristics. More research is needed to develop recommendations for the safe and efficacious use of fermented wet mixes and enzyme supplements in the commercial pig fattening systems.

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Corresponding Author

dr. Tomasz Schwarz, Ph.D., University of Agriculture in Krakow, Institute of Animal Sciences, Department of Swine and Small Animal Breeding, Al. Mickiewicza 24/28, 30-059 Kraków, Poland
Phone: +48 12 662 4072, +48 501 340 249, e-mail: rzschwar@cyf-kr.edu.pl