Journal of Animal and Feed Sciences, 10, 2001, 119 – 131

The nutritional value of differently prepared barley in growing-finishing pigs *

M. Flis[1], W. Sobotka[1], K. Jakubowski[2], L. Mieszkalski[3], Z. Czarnyszewicz[1] and A. Anders[3]

University of Warmia and Mazury
10-718 Olsztyn, Poland
[1]Institute of Animal Nutrition and Feed Management
Oczapowskiego 5
[2]Department of Pathophysiology
Oczapowskiego 13
[3]Institute of Agricultural Machinery and Equipment
Oczapowskiego 11

(Received 18 July 2000; accepted 22 January 2001)

ABSTRACT

The nutritional value of diets containing differently prepared barley was determined in two experiments. Barley grain was prepared in the following ways: hammer milled to medium fine (MH, 900 μm) or fine particles (FH, 600 μm), rolled (R), fine milled and expanded (E). Experiment 1 was conducted on 36 barrows, 28-95 kg BW (9 animals per treatment), fed individually using a ration system. Experiment 2 was carried out on 48 pigs (6 barrows and 6 gilts per treatment), 30-100 kg BW, maintained in groups and fed *ad libitum*. Daily weight gains, feed utilization and stomach lesions were determined in Experiments 1 and 2. In Experiment 1, nutrient and energy digestibilities were also assayed.

It was found that the digestibility of protein (by 3.3 units), fat and energy ($P<0.05$) were better in the FH than in the MH diet and that the FH diet, and contained about 0.5 MJ/kg more metabolizable energy. The digestibility of diet R was also a slightly better ($P>0.05$) and contained more metabolizable energy than MH. The way of preparing barley had a greater effect on growth rate and feed utilization ($P>0.05$) in Experiment 2 in the pigs that were maintained in lots, fed *ad libitum* and gained about 900 g daily than in Experiment 1 in which pigs were fed rations according to standards and gained about 700 g. For the faster growing pigs, rolled and expanded barley had a somewhat greater nutritional value (daily gains 937 and 936 g), medium-fine milled barley had a lower value (865 g).

* Supported by the Committee for Scientific Research, Grant No 5 P06E 057

A greater frequency of oesophageal parakeratosis was found in pigs fed the diets containing fine milled and fine milled and expanded barley.

KEY WORDS: pigs, barley, milling, expanding, digestibility, growth performance, stomach

INTRODUCTION

Decreasing the particle size of feeds used in pig nutrition increases the surface area available to digestive enzymes in the gastrointestinal tract (Wondra et al., 1995a), nutrient digestibility and nutritional value (Wünsche et al., 1987; Wondra et al., 1995a,b). Appropriate particle size enhances growth performance. It was found that every 100 μm reduction in the particle size of maize (from 1200 to 400 μm) increased the growth rate of pigs by 1.3% (Hancock et al., 1999). Taking into account the improved homogeneity of mixtures, digestibility, body weight gains, and feed utilization, it is recommended that grain should be milled to a moderate size of 600 μm (Wondra et al., 1995a), and feed mixes to 400, 500 and 700 μm particles for piglets, fattening pigs and sows, respectively (Gendron, 1997, according to Royer, 1999). Fine milling, particularly using a hammer mill, consumes more electricity, leads to the formation of a large proportion of very fine particles (dust) and to an increase in the frequency of stomach disorders in pigs (Wondra et al., 1995a,b; Ayles et al., 1999). This is why various types of rollers are being used more frequently to mill grain. Our earlier studies (Flis et al., 2000) showed a highly significant decline in protein and fat digestibility in a diet containing rolled barley in comparison with the digestibility of these nutrients in a diet containing fine (600 μm) milled barley, and even slightly worse digestibility in comparison with medium fine (1000 μm) milled barley. The worse digestibility of rolled barley was attributed to the insufficient crushing of the grain used in this experiment. Laurinen et al. (2000) obtained different results in a study on the digestibility of protein and fat in mixtures containing barley rolled using three different types of rollers. Some types of rollers were so effective that the digestibility of the diets containing rolled barley was similar to that of diets with fine milled barley. Expanding is also used to increase the nutritional value of pig feed. Grain alone or feed mixtures containing grain are subjected to this process. In the studies of Vande Ginste and De Schrijver (1998) feeding pigs diets with a high proportion of expanded barley did not have a significant effect on weight gain, feed utilization, or on increasing intestinal and, total digestibility of protein and dry matter, and even had a negative influence on the digestibility of phosphorous and calcium.

The need to more effectively utilize feed nutrients, including grain, in feeding animals and the relative lack of information in the Polish literature on the effect of various methods of preparation of grains on their nutritive value in pig nutrition prompted us to undertake these experiments. The objective of this study was to determine the effect of the degree of milling, crushing or expanding of barley used in complete feeds for growing-finishing pigs on nutrient digestibility, growth performance and stomach health status.

MATERIAL AND METHODS

Preparation of barley

Barley cultivar Rodos was used in both experiments. Medium-fine (MH) and fine (FH) milling was carried out with hammer mill using 6 and 3 mm sieves, respectively. Barley was rolled (R) using a machine with smooth rollers spaced 0.75 mm, which ensured very good crushing of the grain. Fine milled barley (3 mm sieve) was expanded in an Amandus Kahl expander at 95-105°C.

Particle-size distribution and the geometric mean particle size of barley prepared in various ways were determined in three replicates according to Polish Standards (PN 84/R-64798).

Animals and diets

Experiment 1. Four groups of Polish Large White x Duroc castrated males with an average initial body weight (BW) 28.4 kg were fed diets containing MH, FH, R and E barley and rapeseed- and soyabean meal as main protein sources (Table 1). The nutritive value of mixtures and feeding scale were applied according to the Nutrient Requirement of Pigs (1993). The pigs were housed in individual metabolic cages and fed on rations, 1.5-3.0 kg per day, moistend 1:1 with water, and given in two meals. The pigs had free access to automatic drinkers. Nutrient digestibility was determined twice on 5 barrows of each group: on pigs of 53 kg BW fed on grower feed and on animals of 78 kg fed a finisher. Faeces were collected over 6-day periods, samples of 20% were taken from daily collections and frozen. Dry matter, crude ash, ether extract, crude fibre, NDF, and energy were determined in samples dried in 60°C, nitrogen in fresh defrosted samples. Digestibility coefficients and the equation developed by Hoffmann and Schiemann with the adjustments by Muller and Kirchgessner (Nutrient Requirement of Pigs, 1993) were used to calculate the metabolizable energy value of the feeds.

Experiment 2 was conducted at a commercial farm. Four groups of 6 Polish Landrace x Duroc x Hampshire barrows and 6 gilts with average initial weight 30 kg were housed in groups in pens with a concrete floor and rubber matting in one part. Each pen had one automatic feeder with an automatic nipple drinker. The pigs were fed diets containing barley prepared in the same way as in Experiment 1.

TABLE 1

Ingredients and composition of experimental grower and finisher feed mixtures (g/kg) in Experiments 1 and 2

Item	Growth and digestibility trials		Growth trials	
	Experiment 1		Experiment 2	
	Grower	Finisher	Grower	Finisher
Ingredients				
barley[1]	741.8	805.7	746.8	812.8
soyabean meal	100.0	50.0	110.0	60.0
rapeseed meal	100.0	100.0	90.0	90.0
meat-and-bone meal	35.0	20.0	35.0	20.0
dicalcium phosphate	3.0	3.0	2.0	2.0
limestone	8.0	9.0	4.0	3.0
salt	4.0	4.0	3.0	3.0
L-lysine HCL (78%)	1.2	1.3	1.2	1.2
vitamin and mineral premix[2]	7.0	7.0	5.0	5.0
Agricid[3]	-	-	3.0	3.0
Composition analyzed				
dry matter	874.5	876.1	879.3	872.2
crude ash	47.0	40.8	47.7	42.0
crude protein	173.9	149.6	167.9	149.5
ether extract	23.5	21.5	22.1	24.2
crude fibre	47.6	46.9	55.4	53.3
NDF - fibre	174.9	184.4	nd	nd
gross energy, MJ/kg	16.26	16.18	16.40	16.69
Composition calculated[4]				
lysine	9.0	7.5	9.0	7.5
methionine	2.8	2.5	2.7	2.4
threonine	6.2	5.4	6.2	5.8
Ca	7.9	6.8	7.6	5.9
P	6.4	5.7	6.1	5.5
ME, MJ/kg	12.18	12.13	12.21	12.16

[1] barley were differently ground or processed; medium hammer milled = group MH; fine hammer milled = group FH; rolled = group R; fine hammer milled and expanded = group E

[2] premix used in Experiment 1 were on wheat middlings carrier but in Experiment 2 on ground limestone carrier

[3] preparation with lactic acid

[4] calculated according to Nutrient Requirement of Pigs. Nutritive Value of Feeds (1993)

The composition and nutrient value of the feed mixtures are presented in Table 1. *Ad libitum* feeding was used throughout the experiment. Feed consumption was measured as the difference between the amount of feed put into the feeders and the estimated amount of scattered and left feed.

Carcass and stomach evaluation

At the end of experiments, the pigs were slaughtered in slaughterhouse. The hot carcass dressing percentage and meat percentage were determined according to the EUROP system using an FOM 100 ultrasonic apparatus.

Stomach health status was evaluated immediately after slaughter. The stomachs were cut open along the greater curvature, emptied and rinsed with water. The condition of the mucous membrane was determined macroscopically. A stomach score was assigned using a 0-4 point scale: 0 = normal, 1 = slight parakeratosis, 2 = moderately advanced parakeratosis, hyperaemia or petechia, 3 = extensive parakeratosis, 4 = ulcer.

Chemical analysis

The nutrient contents of feeds and faeces were determined by conventional methods (AOAC, 1990). The gross energy content in feed mixtures and faeces was determined by combustion in a calorimeter with an adiabatic bomb. The contents and gelatinization of starch in expanded barley were determined by the method of Tsuge et al. (1990).

Statistical analysis

One-way analysis of variance and the Duncan multiple range test were used to analyze the results of Experiment 1 (digestibility, daily gains, feed utilization, carcass dressing percentage, and meat percentage) and Experiment 2 (initial and final body weight, daily gains, carcass dressing percentage and meat percentage).

RESULTS AND DISCUSSION

Particle size

Medium-fine milled barley (MH) had a considerable proportion of large (over 1020 μm) particles (42-43%) and a small proportion of very fine particles (<430 μm, 15-17%) (Table 2). Fine milled barley (FH) contained few large particles (14-17%) but also contain less very fine particles (24-28%). The average size of barley

TABLE 2

Particle size distribution (% on weight basis), mean geometric particle size of ground barley and starch gelatinization of expanded barley (Experiments 1 and 2)

Particle size, μm	Experiment 1				Experiment 2			
	MH	FH	R	E[1]	MH	FH	R	E[1]
5000 <			2.5				4.0	
4000-5000			11.8				16.0	
3000-4000	2.3	0.8	17.1	0.1	3.9	0.4	23.0	0.1
2000-3000	3.9	0.5	18.5	1.0	3.5	0.4	11.7	0.3
1500-2000	20.6	4.4	24.6	5.4	21.5	6.4	23.3	5.0
1020-1500	15.2	8.7	7.6	8.2	14.2	9.9	7.7	8.8
600-1020	36.4	49.4	10.0	47.8	36.8	50.1	8.8	48.6
430-600	4.3	8.3	1.3	8.1	5.0	8.8	1.0	10.1
250-430	9.2	15.4	2.9	15.4	8.6	14.0	1.9	15.3
< 250	8.1	12.5	3.7	14.0	6.5	10.0	2.6	11.8
Mean geometric particle size, μm	929	610	1940	596	920	648	2120	606
Starch content, %				63.0				60.8
Starch gelatinization after expanding, %				37.0				46.8

[1] before expanding

particles in MH was 929 and 920 μm in Experiments 1 and 2, respectively. Milled grain that is less homogenous in terms of particle size is often used in feed mixtures for pigs (Ślaska-Grzywna, 1981). The average particle size of FH fine milled barley was 610 and 648 μm. Gendron (1997, according to Royer, 1999) recommends even finer milling of feeds for growing pigs, to 500 μm. Rolled barley had a wider range of particle size than milled grain and a large average particle size (1940 and 2120 μm). Sieve analysis of rolled grains does not give a good idea about how well the grain is cracked. Even very well rolled grain has large particles between 2000 to 4000 μm in size, especially rolled barley, which contains hulls that have not been crushed.

The technical difficulties in expanding barley have been described by Laurinen et al. (1998). The degree of gelatinization of starch was 37% in Experiment 1 and 46.8% in Experiment 2.

Digestibility of diets

Fine milled (FH) barley was better digested than medium-fine milled (MH). In grower diets crude protein, gross energy and ether extract digestibility of FH, containing fine milled barley, were better than in the MH diet containing medium-fine milled grain (3.4, and 2.7, P<0.05 and 25.8, P<0.01 units, respectively; Table 3). In the finisher FH diet, only crude protein and ether extract digestibility were greater than in the MH diet (P<0.05). Similarly as in our experiment, Wünsche et al. (1987) and Wondra et al. (1995a) found that increasing the fineness of milled grain increases digestibility. This relationship was not found in the studies of Laurinen et al. (2000), in which the digestibility of grain milled fine and very fine was determined.

Taking into account its effect on digestibility, rolling barley was a somewhat less effective method of grinding than fine milling, but slightly more effective than medium-fine milling. The protein and energy of grower and finisher R diets were digested slightly better (P>0.05) and the ether extract was significantly better (P<0.05) than in diet MH.

Expanding fine milled barley lowered the digestibility of crude protein, 72.1 vs 76.8% in the grower diet (P<0.01) and 75.3 vs 78.8% in the finisher diet (P<0.05). The digestibility of other components of diet E, containing expanded barley, was similar to that in the FH diet containing fine milled barley. Despite the considera-

TABLE 3

Digestibility of the feeds mixtures (%) containing differently ground or expanded barley (Experiment 1)

Item		Feed mixtures				SE
		MH	FH	R	E	
Grower diets,	n	5	5	5	4	
crude protein		73.4^{bc}	76.8^{aA}	75.6^{ab}	72.1^{cB}	0.41
ether extract		30.3^{B}	56.1^{A}	60.8^{A}	58.1^{A}	1.42
crude fibre		31.1	33.1	28.8	31.9	0.51
NDF		56.8	57.4	57.0	58.3	0.49
N-free extractives		88.0	89.2	88.9	88.4	0.16
gross energy, MJ/kg		77.6^{b}	80.3^{a}	79.6^{ab}	78.8^{ab}	0.26
ME, MJ/kg[1]		11.93	12.43	12.35	12.15	
Finisher diets,	n	5	5	5	5	
crude protein		75.5^{b}	78.8^{a}	77.3^{ab}	75.3^{b}	0.31
ether extract		45.3^{b}	67.2^{a}	64.7^{a}	64.3^{a}	1.68
crude fibre		29.1	30.6	30.0	32.7	0.70
NDF		58.6	59.4	59.1	60.1	0.36
N-free extractives		88.2	89.7	89.6	89.2	0.18
gross energy, MJ/kg		78.8	81.2	80.8	79.8	0.25
ME, MJ/kg[1]		12.24	12.70	12.62	12.52	

SE standard error of mean

[1] calculated from digestible nutrients

^{a,b,c} – P ≤ 0.05; ^{A,B} – P ≤ 0.01

ble degree of gelatinization of starch in expanded barley (37%), the digestibility of N-free extractives and energy of diet E did not increase. The digestibility results obtained in this study are similar to the values obtained in earlier experiments. A tendency towards decreasing digestibility of components of diets containing expanded barley was found in the studies of Laurinen et al. (1998). A similar trend towards decreased digestibility of expanded diets containing a large proportion of barley was observed in the studies of Vande Ginste and De Schrijver (1998). The lack of a favourable effect of expanding barley on digestibility may result from greater digesta viscosity caused by the increased content of soluble nonstarch polysaccharides (NSP) resulting from expanding. Edwards (1999) explains the lack of a positive effect of expanding on the nutritive value of some diets in pig nutrition by the rise in the proportion of soluble NSP and deactivation of feed enzymes.

The amount of metabolizable energy in the diets calculated from the content of digestible components differed. The FH diets had higher energy contents (12.43 and 12.70 MJ/kg, for grower and finisher, respectively), the MH diets had the least (11.93 and 12.24 MJ/kg). The difference in the metabolizable energy content between the FH and MH diets was the largest and equaled about 0.5 MJ/kg.

Growth performance

The methods of preparing barley for inclusion in the diets did not have a significant effect on daily weight gains of pigs in Experiment 1, which throughout the experimental period (28-95 kg BW) gained 706-732 g (Table 4). The animals fed diet R, with rolled barley, grew somewhat better (by about 3%) than those fed medium-fine milled or expanded barley. Feed utilization throughout the experiment equaled 3.16-3.22 kg/kg and did not differ significantly. Pigs fed the rolled barley (R) diet consumed less feed by 0.12-0.16 kg/kg, i.e., by 4-5%, in comparison with other groups.

The hot carcass dressing percentage was similar (77.9-78.8%). The meat percentage of the carcasses of groups MH, FH and E was smaller (47.9-49.8%), and in group R greater (52.0%), but the differences were not significant.

In Experiment 2, average daily intake of diet FH containing fine milled barley, was slightly lower in the growing, finishing and entire period of fattening than of the diets containing medium-fine milled, rolled, or expanded barley, MH, R, E, respectively (Table 5). The rolled barley diet (R) was consumed in smaller amounts only in the growing period. Smaller daily consumption of fine milled diets (400 μm) than medium-fine milled diets (800 μm) was also seen in the study by Wondra et al. (1995b), on growing pigs from 55 to 113 kg BW.

In the first period of growth (30-70 kg BW), no significant differences were found in the daily gains of pigs fed diets containing differently prepared barley.

TABLE 4

Growth performance (Experiment 1)

Item	Group				SE
	MH	FH	R	E	
Number of animals	9	9	9	9	
Initial body weight, kg	28.5	29.0	27.6	28.7	0.83
Final body weight, kg	95.6	95.9	95.1	95.4	0.69
Feeding period, days	94.6	93.7	92.4	94.6	
Daily feed intake (28-95 kg BW), kg	2.34	2.34	2.29	2.31	0.01
Daily weight gain, g					
28-63 kg	721	686	722	655	10.08
63-95 kg	701	755	750	757	16.81
28-95 kg	710	716	732	706	10.50
Feed conversion ratio, kg/kg					
28-63 kg	2.71	2.85	2.69	2.99	0.04
63-95 kg	4.08	3.76	3.71	3.60	0.09
28-95 kg	3.32	3.30	3.16	3.28	0.05
Dressing percentage	78.2	78.1	77.9	78.8	0.22
Meatness of carcasses, %	49.8	47.9	52.0	49.6	0.74
Stomach morfology, n	8	8	9	9	
normal	3	1	3	2	
parakeratosis mild	0	0	1	0	
parakeratosis moderate	1	3	0	3	
parakeratosis severe	0	0	0	0	
ulcers	0	0	0	0	
hyperaemia and petechia	6	8	6	7	
stomach score	1.75	2.75	1.44	2.22	

Pigs in group MH had smaller gains, particularly in comparison with the groups fed rolled and expanded barley (885 g vs 922 and 918 g, respectively). In the final period of fattening (70-100 kg BW), differences in growth rates were more pronounced. Pigs fed the diets with rolled (R) and expanded (E) barley grew best, the poorest growth was in pigs receiving the medium-fine milled diet, MH ($P<0.01$). During the entire period of fattening, daily weight gains did not differ significantly, but in groups R and E they were 8% higher than in MH ($P=0.13$) and 3.8% greater than in group FH.

The considerable, ~200 g, difference in the daily weight gain of pigs in Experiments 1 and 2 is difficult to explain. In part it may have resulted from the different

TABLE 5

Growth performance (Experiment 2)

Item	Group				SE
	MH	FH	R	E	
Number of animals	12	12	12	12	
Initial body weight, kg	29.8	30.2	30.1	29.8	0.23
Final body weight, kg	98.4	99.3	101.1	101.0	0.66
Feeding period, days	79.6	77.0	76.0	76.3	
Daily feed intake, kg					
30-70 kg	2.64	2.48	2.45	2.61	
70-100 kg	3.26	3.14	3.48	3.33	
30-100 kg	2.89	2.77	2.90	2.92	
Daily weight gain, g					
30-70 kg	885	906	922	918	13.43
70-100 kg	825[B]	891[AB]	956[A]	965[A]	15.91
30-100 kg	865	898	937	936	11.26
Feed conversion ratio, kg/kg					
30-70 kg	2.98	2.74	2.66	2.85	
70-100 kg	3.94	3.55	3.67	3.49	
30-100 kg	3.35	3.09	3.10	3.13	
Dressing percentage	76.0	77.4	75.8	76.5	0.38
Meatness of carcasses, %	49.4	49.7	49.3	49.9	0.69
Stomach morfology, n	10	11	11	11	
normal	2	2	4	1	
parakeratosis mild	2	1	0	8	
parakeratosis moderate	0	0	1	0	
parakeratosis severe	0	0	0	0	
ulcers	0	1	0	0	
hyperaemia and petechia	8	10	6	5	
stomach score	1.80	2.27	1.27	1.63	

A,B – $P \leq 0.01$

feeding systems used and consequent differences in the average daily feed intake (2.32 kg in Experiment 1 and 2.85 kg in Experiment 2) and in part by the slightly different genotypes of the animals in the two experiments.

In Experiment 2 feed utilization was better in animals fed the fine milled, rolled, and expanded barley (3.09-3.13 kg/kg) and worse in pigs given diets containing medium-fine milled barley (3.35 kg/kg).

Hot carcass dressing percentage did not differ significantly, but was slightly higher in the group fed fine milled barley (77.4%) and smaller in pigs receiving the rolled barley diet (75.8%). The carcass meat percentage ranged from 49.3 to 49.9%.

The methods used to prepare the barley fed in rapeseed-soyabean diets had varied effects on the growth performance of pigs. In Experiment 1 the pigs were fed using a ration system and gained about 700 g daily. These pigs were practically did not responded to the forms of barley that differed in terms of digestibility and metabolizable energy contents. In Experiment 2 pigs were fed *ad libitum,* consumed more feed and gained more, 900 g daily. The manner of preparing barley had a greater effect on the analyzed parameters. Diets containing rolled, expanded and fine milled barley were more effective than the medium-fine milled diets. On average, during fattening, 0.30 kg body weight gain was obtained from 1 kg of MH diet and 0.32 kg from diets FH, R and E. The results of both experiments show that in barley-rapeseed-soyabean diets that are balanced in terms of protein, increasing the energy value by the appropriate grinding or expanding of barley has a beneficial effect on daily weight gain only in pigs with greater growth rates. Earlier studies (Chabiera et al., 1994; Urbańczyk, 1998) have also shown that the growth rate of pigs increases when the energy concentration increases in diets balanced in terms of protein quantity and quality.

Stomach morphology

The condition of the stomachs of pigs in both experiments was good (Tables 4 and 5). With only one exception, no ulcers were found. In pigs fed expanded and fine milled barley, a higher frequency of parakeratosis in the *pars oesophagea* was found, but only in a slight or moderately advanced degree. Wondra et al. (1995a) found greater unfavourable changes in pig stomachs than in our study. Decreasing the particle size of maize in the diets of pigs (55-114 kg BW) from 1000 to 600 μm caused the ulceration index of the *pars oesophagea* to rise from 1.1 to 1.5 and the keratinization index, from 1.4 to 2.5. In these studies the least unfavourable changes, including hyperaemia and petechia, were found in pigs fed rolled barley. The reasons for the greater frequency of stomach disorders in pigs fed fine milled feeds are not well understood. In the studies of Regina et al. (1999) a lower dry matter content was found in the stomach contents of pigs fed fine milled diets (600 μm) than coarse-milled (900 μm) ones. According to the cited authors, the lower dry matter content and greater liquidity of the stomach contents together with the hydrochloric acid and pepsin secreted by the stomach may play a significant role in initiating pathologic lesions.

CONCLUSIONS

Among the four evaluated diets containing barley prepared by various methods (MH, FH, R, E) the greatest nutrients digestibility and metabolizable energy content were found in diet FH with fine milled barley (600 μm), the lowest in diet MH with medium-fine milled barley (900 μm).

The way of preparing the barley had a greater effect on the daily weight gains of pigs fed *ad libitum* that were gaining about 900 g daily (Experiment 2) than on those fed in accordance with standards and gaining about 700 g daily (Experiment 1). For pigs with higher growth rates, rolled barley and expanded barley (fine milled first) had a slightly greater value, fine milled barley, a moderate one, and medium-fine milled, the lowest. In pigs fed expanded grain or fine milled barley parakeratosis of the stomach was, however, more frequent.

REFERENCES

AOAC, 1990. Official Methods of Analysis. 15th Edition. Association of Official Analytical Chemists. Washington, DC

Ayles H.L., Friendship R.M., Bubenik G.A., Ball R.O., 1999. Effect of feed particle size and dietary melaton supplementation on gastric ulcers in swine. Can J. Anim. Sci. 79, 179-185

Chabiera K., Kotarbińska M., Raj S., Fandrejewski H., Weremko D., 1994. Effect of intake of metabolizable energy and lysine on the performance and chemical body composition of growing pigs (in Polish). In: Proceedings of 1st Conference In: „Recent Advances in Swine Nutrition", Jabłonna (Poland), pp. 38-41

Edwards A.C., 1999. Feed processing and feeding management to enhance nutrient utilization in commercial livestock production. Rec. Advan. Anim. Nutr., Australia 12, 137-144

Flis M., Sobotka W., Mieszkalski L., Mańkowski S., 2000. Digestibility and growth performance of growing-finishing pigs fed diets with differently ground or expanded barley. Czech J. Anim. Sci. 45, 451-455

Hancock J.D., Wondra K.J., Taylor S.L., Mavromichalis I., 1999. Strategies to improve growth performance and decrease cost of gain in pigs. Feed Mix 7 (4), 18-21

Laurinen P., Valaja J., Näsi M., Smeds K., 1998. Effects of different expander processing conditions on the nutritive value of barley and wheat by-products in pig diets. Anim. Feed Sci. Tech. 74, 213-227

Laurinen P., Siljander-Rasi H., Karhumen J., Alaviuhkola T., Näsi M., Tuppi K., 2000. Effects of different grinding methods and particle size of barley and wheat on pig performance and digestibility. Anim. Feed Sci. Tech. 83, 1-16

Nutrient Requirement of Pigs. Nutritive Value of Feeds (in Polish), 1993. The Kielanowski Institute of Animal Physiology and Nutrition (Editor). Jabłonna (Poland)

PN-84/R-64798. Feed. Determination of Granulation (in Polish)

Regina D.C., Eisemann J.H., Lang J.A., Argenzio R.A., 1999. Changes in gastric contents in pig fed a finely ground and pelleted or coarsely ground meal diet. J. Anim. Sci. 77, 2721-2729

Royer E., 1999. La granulometrie des aliments porcins fabriques á la ferme. Techn. Porc. 2 (4), 29-32

Ślaska-Grzywna B., 1981. Study on basic indicators run quality of grinders in small feed mills (in Polish). Biul. inf. Przem. Pasz. 4, 26-35

Tsuge H., Hishida M., Iwasaki H., Watanabe S., 1990. Enzymatic evaluation for the degree of starch retrogradation in foods and feedstuffs. Starch 42, 213-216

Urbańczyk J., 1998. Effects of feeding intensity and dietary energy and amino acid concentration of fattening and slaughter results of pigs high in lean (in Polish). Rocz. Nauk. Zoot., Rozprawy habil. No 8, pp. 1-62

Vande Ginste J., De Shrijver R., 1998. Expansion and pelleting of starter, grower and finisher diets for pigs: effects on nitrogen retention, ileal and total tract digestibility of protein, phosphorus and calcium and in vitro protein quality. Anim. Feed Sci. Tech. 72, 303-314

Wondra K.J., Hancock J.D., Behnke K.C., Hines R.H., Stark C.R., 1995a. Effects of particle size and pelleting on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. J. Anim. Sci. 73, 757-763

Wondra K.J., Hancock J.D., Behnke K.C., Stark C.R., 1995b. Effects of mill type and particle size uniformity on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. J. Anim. Sci. 73, 2564-2573

Wünsche J., Herrmann U., Meinl M., Hennig U., Kreienbring F., Zwierz P., 1987. Einfluß exogener Faktoren auf die präzäkale Nährstoff und Aminosäurenresorption, ermittelt an Schweinen mit Ileo-Rektal-Analstomosen. Arch. Anim. Nutr. 37, 745-764

STRESZCZENIE

Wartość pokarmowa różnie przyrządzonego ziarna jęczmienia w żywieniu tuczników

W dwóch doświadczeniach określono wartość pokarmową mieszanek paszowych z udziałem różnie przyrządzonego jęczmienia. Doświadczenie 1 przeprowadzono na 36 wieprzkach (28-95 kg m.c.) żywionych indywidualnie systemem dawkowanym, a doświadczenie 2 na 48 świniach (24 wieprzki i 24 loszki), 30-100 kg m.c., żywionych grupowo, do woli. Zastosowano cztery mieszanki z udziałem jęczmienia: MH-ześrutowanego średnio miałko (900 μm), FH-ześrutowanego miałko (600 μm), R-gniecionego, E-ześrutowanego miałko i ekspandowanego. Oznaczono przyrosty dzienne, wykorzystanie paszy i stan zdrowotny żołądków (doświadczenia 1 i 2) oraz strawność składników pokarmowych i energii mieszanek paszowych (doświadczenie 1).

Stwierdzono, że strawność białka (o 3,3 jednostek), tłuszczu i energii ($P<0.05$) mieszanek paszowych FH była lepsza niż mieszanek MH; zawierały one o około 0.5 MJ/kg więcej energii metabolicznej. Strawność mieszanki R była także trochę lepsza ($P>0.05$), a zawartość energii metabolicznej była większa niż MH. Sposób przyrządzenia jęczmienia miał większy wpływ na tempo wzrostu i wykorzystanie paszy ($P>0.05$) w doświadczeniu 2, u świń utrzymywanych grupowo, żywionych do woli i przyrastających po około 900 g dziennie niż w doświadczeniu 1, u świń żywionych według norm i przyrastających po około 700 g. Dla szybciej rosnących świń trochę większą wartość odżywczą miał jęczmień gnieciony i ekspandowany (przyrosty dobowe 937 i 936 g), a mniejsząześrutowany średnio miałko (przyrosty 865 g). Większą częstotliwość występowania parakeratozy przełykowej części żołądka stwierdzono u świń żywionych mieszankami z jęczmieniemześrutowanym miałko (FH) orazześrutowanym miałko i ekspandowanym (E) niż u pozostałych.