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Performance of Growing-Finishing Pigs Fed Diets Containing Normal or Low Lignin-High Fat Oat Processed Using a Hammer Mill or Roller Mill

Thacker, P.A.
Department of Animal Science, University of Saskatchewan, 51 Campus Drive, Saskatoon, Saskatchewan, Canada S7N 5A8

Abstract: The objectives of the following study were to compare a recently developed low lignin- high fat oat with regular oat as an energy source for use in diets fed to growing-finishing pigs and to compare hammer milling and roller milling as methods of processing oats. A total of 40 crossbred grower pigs (20 barrows and 20 gilts) were assigned to one of five dietary treatments in a factorial design experiment. The control diet was formulated using barley and soybean meal while four experimental diets were formulated in which 40% of either normal or low lignin-high fat oat was substituted for barley. The oats were either ground or rolled. Particle size analysis indicated that the average particle size of the grower diets was 884, 1037, 1420, 1031 and 1501 μm while for the finisher diets, the average particle size was 800, 869, 1250, 854 and 1098 μm for the barley, ground normal oat, rolled normal oat, ground low lignin-high fat oat and rolled low lignin-high fat oat diets respectively. Digestibility coefficients for pigs fed ground oats were significantly ($p<0.05$) higher than those for pigs fed rolled oat while there was no difference ($p>0.05$) in nutrient digestibility between pigs fed normal and low lignin-high fat oat. During the growing period (35.1 to 71.4 kg) as well as over the entire experiment (35.1 to 112.5 kg), there were no differences ($p>0.05$) in daily gain, feed intake or feed conversion between pigs fed normal or low lignin-high fat oat or between pigs fed ground or rolled oat diets. During the finishing period (71.4 to 112.5 kg), feed intake and feed conversion were poorer ($p<0.05$) for pigs fed the low lignin-high fat oat compared with the barley diet. There were no differences in carcass traits between pigs fed normal and low lignin-high fat oat or between pigs fed rolled and ground oats. The overall results of this experiment indicate that both normal and low lignin-high fat oat can substitute for barley at levels as high as 40% of the diet without hindering pig performance. Since the average yield of oat can be equal or higher than barley with lower input costs, a re-examination of feeding recommendations regarding oat in swine rations seems warranted. In addition, since pig performance and carcass traits were not affected by processing method and roller mills have been shown to have lower-energy requirements, lower maintenance costs, quieter operation, and more exact control of particle size than hammer mills, there may be some advantage for pig producers to consider roller mills rather than hammer mills for use in processing pig feeds.

Key words: Swine, oats, processing, digestibility, growth, carcass composition

INTRODUCTION

Cereal grains are typically processed before they are mixed into diets fed to swine[1]. This processing nearly always involves grinding to disrupt the intact kernel and reduce particle size[2]. Grinding increases the surface area of the grain, allowing for greater interaction with digestive enzymes, which results in an increase in the digestibility of energy and other nutrients contained in the grain as well as improving feed efficiency[3-5]. Grinding also improves the handling and mixing characteristics of the diet, although excessive grinding will increase the energy costs of feed processing and may result in feed bridging, dust problems and an increase in the incidence of gastric ulcers[6].

Of the various mill designs that can be used to grind cereal grains, hammer mills are by far the most commonly used in the production of pig feeds[7]. This is largely due to their simplicity, ease of operation and low upkeep[1]. However, McEllhiney[8] suggested several advantages for roller mills compared with hammer mills including lower-energy requirements, quieter operation, more exact control of particle size, reduced moisture loss from the grain and lower maintenance costs. Wondra[5] suggested that the more uniform particle size obtained from roller mills may increase nutrient digestibility for growing-finishing pigs.

Domestic oats (*Avena sativa*) are not widely utilized as an energy source in swine rations[9,10]. The principle reason for this is that approximately one-third of the oat grain is hull resulting in a high dietary fibre content[11]. The fibrous material within the hull acts as a physical barrier to efficient digestion in the gut[12]. Therefore, it would seem logical to assume that the particle size produced when grinding oats for inclusion in the diet could have a significant effect on the ease with which digestive enzymes reach the nutrients in the endosperm and on the nutritive value of the grain when fed to pigs[13].

Dietary fibre is defined as the sum of non-starch polysaccharides and lignin[14]. Most non-starch polysaccharides can be degraded to some degree in the digestive tract of the pig[14] whereas lignin is virtually indigestible[15]. Since the lignin content of oat is almost twice that of any of the commonly used cereal grains[14], a reduction in the lignin content of oat may be beneficial in improving its nutritional value for swine. In addition, inclusion of fat increases the energy content of swine diets[16] and has been shown to improve the feeding value of diets containing 40% oat when fed to growing-finishing pigs[17]. Therefore, increasing the fat content of oat may be another way to improve its nutritional value for swine.

A breeding project was recently undertaken at the University of Saskatchewan to develop a low acid detergent lignin hull-high fat oat for use in livestock feeding. The following study was conducted to compare this recently developed oat with regular oat as an energy source for use in diets fed to growing-finishing pigs and to compare the performance of pigs fed diets containing oat processed using either a roller mill or a hammer mill.

MATERIALS AND METHODS

Acquisition of oat samples: The low lignin-high fat oat sample used in the present trial is a breeding line developed at the University of Saskatchewan, Crop Development Centre (CDC). The breeding line was developed from a cross between AC Assiniboia (donor of the low acid detergent lignin hull trait) and a CDC breeding line SA96121 (donor of the high fat trait). A single plant, identified as both low lignin and high fat, was bulked to form the low lignin hull, high fat groat CDC breeding line that was tested in this experiment.

The normal-fat oat variety used was Derby[18]. It is one of the most commonly grown oat varieties on the Canadian Prairies due to its high yield, excellent grain quality, good straw strength and relatively low groat fat. A chemical analysis of the two oat varieties tested as well barley and soybean meal is shown in Table 1.

Growth trial: A total of 40 crossbred pigs (Camborough 15 Line female × Canabred sire, Pig Improvement Canada Ltd., Airdrie Alberta) weighing an average of 35.1±4.7 kg were assigned on the basis of sex, weight and litter to one of five dietary treatments in a 2×5 factorial design experiment. The main effects tested were sex of pig (barrows vs. gilts) and diet.

The control diet was formulated using ground barley and soybean meal while four experimental diets were formulated in which 40% of either normal or low lignin-high fat oat was substituted for barley. The oat was ground through either a hammer mill or a roller mill. The hammer mill was a Jacobson 170F8 (Jacobson Products, Minneapolis, MN) equipped with a 50 horsepower motor and a 1/4" screen. The roller mill was a Series 9 Grain Roller Mill Model J (Rosskamp Huller Manufacturing Company, Cedar Falls, IA).

During the growing period (35.1 to 71.4 kg), the experimental diets were formulated to supply 1.05% lysine while in the finishing period (71.4-112.3 kg), the diets were formulated to supply 0.75% lysine. Diets containing oat were supplemented with canola oil to compensate for the expected lower energy of oat compared with barley. All diets were supplemented with sufficient vitamins and minerals to meet or exceed the levels recommended by the National Research Council[19]. The diets were pelleted using low-pressure steam at approximately 60°C.

The pigs were housed in unisex groups of four in 2.7×3.6 m concrete floored pens and were provided water ad libitum. The pens were equipped with four individual feeders. Each pig was allowed access to its own individual feeder for 30 min twice daily (08:00 h and 15:00 h). Individual body weight, feed consumption and feed conversion were recorded weekly. Four castrates and four gilts were fed each diet. Pigs were assigned to feeders in such a way as to minimize the potential for treatment effects to be confounded with environmental effects.

Digestibility determination: Total tract digestibility coefficients for dry matter, crude protein and gross energy were determined using four barrows per treatment starting at an average weight of 62.3 kg. The pigs were housed under identical conditions as those used in the growth trial and were fed the same diets as those used during the growing stage modified only by the addition of 0.35% chromic oxide as a digestibility marker. Marked feed was provided for a seven-day acclimatization period, followed by a three-day fecal collection. Fecal collections were made by bringing animals into a clean room immediately after feeding and recovering freshly voided feces. The fecal samples were frozen for storage. Prior to analysis, the samples were dried in a forced air oven dryer at 66°C for 60 h, followed by fine grinding (0.5 mm screen). Digestibility coefficients were calculated using the equations for the indicator method described by Schneider and Flatt[20].

Table 1: Chemical analysis of main ingredients used to determine the effect of processing on the nutritive value of normal and low lignin-high fat oats fed to growing-finishing pigs

	Barley	Derby oat	High fat-low lignin oat	Soybean meal
Chemical composition (% as fed)				
Moisture	9.59	5.95	7.87	7.89
Crude protein	13.42	15.63	14.09	47.43
Ash	1.91	2.73	2.95	6.54
Ether extract	1.89	4.00	5.74	1.04
Neutral detergent fiber	17.46	33.55	27.87	8.16
Acid detergent fiber	5.73	14.74	13.34	5.28
Lignin	0.79	2.05	1.12	0.34
Calcium	0.05	0.06	0.08	0.34
Phosphorus	0.34	0.31	0.35	0.72
Essential amino acid content (% as fed)				
Arginine	0.57	0.92	0.73	3.58
Histidine	0.32	0.34	0.30	1.21
Isoleucine	0.39	0.39	0.39	2.41
Leucine	0.85	0.98	0.86	3.91
Lysine	0.48	0.51	0.51	3.16
Methionine and Cystine	0.39	0.44	0.44	1.70
Phenylalanine	0.48	0.61	0.55	1.48
Threonine	0.28	0.31	0.31	2.33
Valine	0.38	0.44	0.44	2.44

Carcass measurements: All pigs were slaughtered at a commercial abattoir at an average weight of 112.5±2.3 kg. Carcass weight was recorded and dressing percentage calculated. Carcass fat and lean measurements were obtained with a Destron PG 100 probe placed over the 3rd and 4th last ribs, 70 mm off the midline. These values were then used in calculating Carcass Value Indices according to the table of differentials in effect at the time of the experiment[21].

Chemical analysis: Samples of barley, soybean meal and the two oat varieties as well as the grower and finisher rations were analyzed for dry matter, ash, crude protein, ash and ether extract according to the methods of the Association of Official Analytical Chemists[22]. The calcium and phosphorus content of the growing and finishing rations were also determined according to the methods of the Association of Official Analytical Chemists[22]. Neutral detergent fibre was analysed using the method of Van Soest[23]. An adiabatic oxygen bomb calorimeter (Parr; Moline, Illinois) was used to determine gross energy content. Chromic oxide was determined by the method of Fenton and Fenton[24]. Amino acids were assayed using ion-exchange chromatography with an automatic Amino Acid Analyser (L-8800 Hitachi Automatic Amino Acid Analyzer, Tokyo, Japan) after hydrolyzing with 6 mol L HCl for 24 h at 110°C. Particle size analysis was conducted according to the methods of Benke[25].

Statistical analysis: The data from the performance trial and carcass data were analysed as a 2×5 factorial using the General Linear Model procedure of the Statistical Analysis System Institute, Inc.[26] with the factors in the model consisting of diet and sex of pig as well as their interaction. Digestibility data were analysed as a one-way ANOVA. Treatment means were compared using single degree of freedom orthogonal contrasts. Contrasts tested included a) barley diet vs. normal oat diets b) barley diet vs. low lignin-high fat oat diets; c) normal oat diets vs. low lignin-high fat oat diets d) ground oat diets vs. rolled oat diets. Differences were considered significant when $p<0.05$. Since pigs were fed individually, pigs were considered the experimental unit for all statistical analysis and pen was never considered in any analytical model.

RESULTS

The breeding program to increase the fat content of oats was successful with the low lignin-high fat oat having 30.3% higher (5.74 vs. 4.00) ether extract than the normal oat (Table 1). In addition, the lignin content of the selected oat was 45.3% lower (1.12 vs. 2.05%) than the normal oat. The reduction in lignin content was associated with lower neutral detergent fibre and acid detergent fibre. The essential amino acid contents of the two oat varieties were generally higher than those for barley.

The chemical analysis conducted on the growing and finishing rations confirmed that the diets met the specifications called for in the diet formulation. All diets contained approximately the same crude protein content (Table 2 and 3). The ether extract content of the low lignin-high fat oat containing diets was higher and the neutral detergent fibre content lower than the normal oat containing diets reflecting the chemical composition of the two oat varieties. Grinding or rolling did not have any consistent effects on the nutrient content of the diets.

Table 2: Ingredient composition and chemical analysis of grower diets (35.1-71.4 kg) formulated to determine the effect of processing on the nutritive value of oats fed to growing-finishing pig

	Barley	Ground oat	Rolled oat	Ground low lignin-high fat oat	Rolled low lignin-high fat oat
Ingredients (%)					
Barley (13.42% CP)	70.70	28.54	28.54	28.54	28.54
Derby oats (15.63% CP)	0.00	40.00	40.00	0.00	0.00
High fat-low lignin oat (14.09% CP)	0.00	0.00	0.00	40.00	40.00
Soybean meal (47.43% CP)	22.62	22.91	22.91	22.91	22.91
Limestone	0.94	0.85	0.85	0.85	0.85
Dicalcium phosphate	1.08	1.22	1.22	1.22	1.22
Salt	0.50	0.50	0.50	0.50	0.50
Vitamin-mineral premix	1.00	1.00	1.00	1.00	1.00
Canola oil	3.16	4.98	4.98	4.98	4.98
Chemical analysis (% as fed)					
Moisture	10.33	9.07	9.32	9.33	9.17
Ash	6.06	7.09	6.48	6.76	7.42
Crude protein	20.71	21.58	21.21	21.13	21.57
Neutral detergent fibre	15.32	17.99	17.85	16.29	16.45
Ether extract	5.77	8.86	8.40	10.44	9.30
Calcium	0.69	0.70	0.71	0.68	0.72
Phosphorus	0.60	0.59	0.60	0.59	0.60
Particle size (μm)	884	1036	1420	1031	1501

[1]Supplied per kilogram of diet: 8250 IU vitamin A; 825 IU vitamin D_3; 40 IU vitamin E; 4 mg vitamin K; 1 mg thiamine; 5 mg riboflavin; 35 mg niacin; 15 mg pantothenic acid; 2 mg folic acid; 12.5 μg vitamin B_{12}; 0.2 mg biotin; 80 mg iron: 25 mg manganese; 100 mg zinc; 50 mg Cu; 0.5 mg I; 0.1 mg selenium

Table 3: Ingredient composition and chemical analysis of finisher diets (71.4-112.5 kg) formulated to determine the effect of processing on the nutritive value of oats fed to growing-finishing pigs

	Barley	Ground Oat	Rolled Oat	Ground Low lignin-high fat oat	Rolled Low lignin-high fat oat
Ingredients (%)					
Barley (10.91% CP)	80.38	38.21	38.21	38.21	38.21
Derby oats (15.63% CP)	0.00	40.00	40.00	0.00	0.00
High fat-low lignin oat (14.09% CP)	0.00	0.00	0.00	40.00	40.00
Soybean meal (47.43% CP)	14.52	14.82	14.82	14.82	14.82
Limestone	0.98	0.89	0.89	0.89	0.89
Dicalcium phosphate	0.63	0.77	0.77	0.77	0.77
Salt	0.50	0.50	0.50	0.50	0.50
Vitamin-mineral premix	1.00	1.00	1.00	1.00	1.00
Canola oil	1.99	3.81	3.81	3.81	3.81
Chemical analysis (% as fed)					
Moisture	11.22	10.60	10.30	10.84	10.89
Ash	4.67	4.82	4.51	4.68	4.69
Crude protein	15.91	16.96	16.34	15.77	15.37
Neutral detergent fibre	16.52	18.46	18.12	18.01	17.25
Ether extract	4.25	6.21	6.59	7.66	7.68
Calcium	0.64	0.70	0.64	0.67	0.60
Phosphorus	0.47	0.54	0.51	0.48	0.47
Particle size (μm)	806	869	1250	854	1096

Supplied per kilogram of diet: 8250 IU vitamin A; 825 IU vitamin D_3; 40 IU vitamin E; 4 mg vitamin K; 1 mg thiamine; 5 mg riboflavin; 35 mg niacin; 15 mg pantothenic acid; 2 mg folic acid; 12.5 μg vitamin B_{12}; 0.2 mg biotin; 80 mg iron: 25 mg manganese; 100 mg zinc; 50 mg Cu; 0.5 mg I; 0.1 mg selenium

Particle size analysis indicated that the average particle size of the grower diets was 884, 1036, 1420, 1031 and 1501 μm while the average particle size of the finisher diets was 806, 869, 1250, 854 and 1096 μm for the barley, ground normal oat, rolled normal oat, ground low lignin-high fat oat and rolled low lignin-high fat oat diets respectively (Table 2 and 3).

The amino acid analysis conducted on the growing and finishing rations confirmed that the diets met the specifications called for in the diet formulation (Table 4). During the growing period (35.1 to 71.4 kg), the experimental diets were formulated to supply 1.05% lysine while in the finishing period (71.4-112.3 kg), the diets were formulated to supply 0.75% lysine. These diets would meet the amino acid requirements of pigs with a lean growth potential in excess of 400 g/day[19]. The effects of processing normal or low lignin-high fat oat using either a roller mill or a hammer mill on the digestibility of dry matter, crude protein and energy are shown in Table 5. For dry matter and energy, digestibility coefficients for pigs fed diets formulated using ground barley were significantly ($p<0.05$) higher than those for

Table 4:Amino acid analysis of diets formulated to determine the effects of processing on the nutritive value of oats for growing-finishing pigs

Amino acids (% as fed)	Barley	Ground oat	Rolled oat	Ground low lignin-high fat oat	Rolled low lignin-high fat oat
Grower diets (35.1-71.4 kg)					
Arginine	1.17	1.28	1.23	1.28	1.18
Histidine	0.52	0.53	0.50	0.52	0.49
Isoleucine	0.81	0.84	0.80	0.84	0.77
Leucine	1.44	1.46	1.42	1.48	1.36
Lysine	1.06	1.14	1.05	1.15	1.09
Methionine + Cysteine	0.81	0.77	0.79	0.79	0.70
Phenylalanine	1.04	1.02	1.02	1.04	0.94
Threonine	0.73	0.75	0.73	0.76	0.71
Valine	1.02	1.00	0.98	1.00	0.92
Finisher diets (71.4-112.5 kg)					
Arginine	0.76	0.94	0.85	0.85	0.82
Histidine	0.36	0.40	0.37	0.37	0.36
Isoleucine	0.53	0.62	0.58	0.57	0.56
Leucine	0.97	1.12	1.05	1.02	1.01
Lysine	0.70	0.81	0.74	0.76	0.74
Methionine + Cysteine	0.60	0.61	0.59	0.62	0.62
Phenylalanine	0.73	0.80	0.76	0.76	0.73
Threonine	0.51	0.56	0.52	0.53	0.52
Valine	0.73	0.79	0.75	0.76	0.74

Table 5: Digestibility coefficients for growing-finishing pigs fed normal or low-lignin-high fat oat fed either ground or rolled

	Barley	Ground oat	Rolled oat	Ground low lignin-high fat oat	Rolled Low Lignin-high fat oat	SEM	p-value
Dry matter (%)[w,x,z]	77.41	74.38	68.93	74.88	68.21	0.90	<0.01
Crude protein (%)[z]	79.74	81.97	76.54	81.61	78.98	1.09	0.04
Energy (%)[w,x,z]	77.35	74.27	68.23	75.36	68.92	0.94	<0.01

[w]Orthoginal contrast for barley diet vs. normal oat diets significant at p<0.05, [x]Orthoginal contrast for barley vs. low lignin-high fat oat diets significant at p<0.05, [y]Orthoginal contrast for normal oat diets vs. low lignin-high fat oat diets significant at p<0.05, [z]Orthoginal contrast for ground oat diets vs. rolled oat diets significant at p<0.05

Table 6: Performance of growing-finishing pigs fed normal or low-lignin-high fat oat fed either ground or rolled

	Dietary treatment						Sex of pig			P-values		
	Barley	Ground oat	Rolled oat	Ground low lignin High fat oat	Rolled low lignin-High fat oat	SEM	Barrows	Gilts	SEM	Treat	Sex	T × S
Grower period (35.1-71.4 kg)												
Daily gain (kg)	1.02	1.06	1.04	1.06	1.00	0.036	1.05	1.02	0.022	0.76	0.39	0.56
Daily intake (kg)	2.27	2.25	2.20	2.29	2.23	0.092	2.31	2.18	0.058	0.96	0.11	0.34
Feed conversion	2.22	2.12	2.12	2.16	2.21	0.050	2.20	2.13	0.031	0.45	0.12	0.78
Finisher period (71.4-112.5 kg)												
Daily gain (kg)	1.27	1.23	1.22	1.25	1.17	0.058	1.32	1.13	0.036	0.82	<0.01	0.80
Daily intake (kg)[x]	3.28	3.51	3.36	3.61	3.49	0.098	3.74	3.14	0.062	0.16	<0.01	0.29
Feed conversion[z]	2.65	2.88	2.77	2.91	2.97	0.115	2.87	2.79	0.073	0.32	0.42	0.66
Overall experiment (35.1-112.5 kg)												
Daily gain (kg)	1.13	1.14	1.12	1.15	1.09	0.035	1.17	1.08	0.022	0.83	<0.01	0.87
Daily intake (kg)	2.78	2.86	2.77	2.91	2.86	0.065	2.99	2..68	0.041	0.52	<0.01	0.15
Feed conversion	2.49	2.51	2.47	2.54	2.63	0.069	2.57	2.49	0.044	0.53	0.22	0.70

[w]Orthoginal contrast for barley diet vs. normal oat diets significant at p<0.05, [x]Orthoginal contrast for barley vs. low, lignin-high fat oat diets significant at p<0.05, [y]Orthoginal contrast for normal oat diets vs. low lignin-high fat oat diets significant at p<0.05, [z]Orthoginal contrast for ground oat diets vs. rolled oat diets significant at p<0.05

pigs fed diets formulated using ground normal oat or ground low lignin-high fat oat. In addition, digestibility coefficients for ground oats were significantly (p<0.05) higher than those for rolled oat. However, there was no difference (p>0.05) in the digestibility of dry matter or energy for pigs fed normal oat or low lignin-high fat oat.

For crude protein digestibility, there was no difference (p>0.05) in digestibility between pigs fed ground barley and either of the two oat varieties. There was also no difference (p>0.05) in protein digestibility between pigs fed normal oat and low lignin-high fat oat. However, digestibility coefficients for protein were significantly (p<0.05) lower for pigs fed rolled oat compared with ground oat. The effects of processing normal or low lignin-high fat oat using either a roller mill or a hammer mill on pig performance are shown in Table 6. During the growing period (35.1 to 71.4 kg) as well as over the entire experiment (35.1 to 112.5 kg), there were no differences (p>0.05) in daily gain, feed intake or feed conversion

Table 7: Carcass traits of pigs fed normal or low lignin-high fat oat ground or rolled

	Dietary treatment						Sex of Pig			P-values		
	Barley	Ground Oat	Rolled Oat	Ground low lignin-High fat oat	Rolled low lignin-High fat oat	SEM	Barrows	Gilts	SEM	Treatment	Sex	T × S
Slaughter weight (kg)	113.2	112.5	113.1	111.3	112.7	0.85	113.2	111.9	0.54	0.53	0.09	0.88
Carcass weight (kg)	88.4	87.2	89.4	86.3	87.9	0.76	88.0	87.4	0.48	0.06	0.39	0.57
Dressing percent (%)	78.0	77.5	79.0	77.4	78.0	0.52	77.7	78.1	0.33	0.16	0.43	0.65
Carcass value index	109.6	110.1	110.4	109.4	110.9	0.66	109.4	110.7	0.42	0.52	0.04	0.46
Lean yield (%)	61.8	60.9	61.0	60.6	61.1	0.58	60.4	61.8	0.36	0.64	0.01	0.71
Loin fat (mm)	16.3	17.6	17.8	17.8	17.0	1.07	18.6	16.0	0.68	0.84	0.01	0.73
Loin lean (mm)	61.9	58.8	61.7	55.1	57.9	3.14	57.6	60.5	1.98	0.53	0.31	0.93

[w]Orthoginal contrast for barley diet vs. normal oat diets significant at p<0.05, [x]Orthoginal contrast for barley vs. low lignin-high fat oat diets significant at p<0.05, [y]Orthoginal contrast for normal oat diets vs. low lignin-high fat oat diets significant at p<0.05, [z]Orthoginal contrast for ground oat diets vs. rolled oat diets significant at p<0.05

between pigs fed normal or low lignin-high fat oat or between pigs fed ground or rolled oat diets. During the finishing period (71.4 to 112.5 kg), feed intake and feed conversion were poorer (p<0.05) for pigs fed the low lignin-high fat oat compared with the barley diet. During the finisher period and overall, barrows had higher (p<0.05) weight gain and feed intake than gilts. Feed conversion was unaffected (p>0.05) by sex of pig.

The effects of processing normal or low lignin-high fat oat using either a roller mill or a hammer mill on pig carcass traits performance are shown in Table 7. There were no differences (p<0.05) in carcass traits between pigs fed normal and low lignin-high fat oat or between rolled and ground oats. Barrows had significantly (p<0.05) lower lean yield and loin lean than gilts while loin fat was significantly higher (p<0.05)

DISCUSSION

The recommended particle size for grinding ingredients for use in swine diets is 700-800 μm[27]. Therefore, during the grower period, both the ground and rolled oat diets regardless if based on normal or low lignin-high fat oat had higher than recommended particles sizes. During the finishing period, diets based on rolled oats had higher than recommended particle sizes while diets based on ground oats were closer to the recommended particle size.

Digestibility coefficients for pigs fed rolled oats were significantly lower than those obtained for pigs fed ground oats. As such, these findings conflict with previous research which showed either higher nutrient digestibility for feed produced by a roller mill compared with a hammer mill[5] or no difference in nutrient digestibility for feed produced by a roller mill compared with a hammer mill[3]. However, in the previous study, particle size was similar for the diets produced by the two types of mills while in the present study, the roller mill produced a significantly larger particle size. There was no difference in nutrient digestibility for diets formulated using normal oat compared with low lignin-high fat oat which supports our previous findings[28].

One obvious explanation for the lower digestibility coefficients obtained for pigs fed rolled diets compared with ground diets is the larger particle size of these diets. Giesemann[29] reported lower digestibility of dry matter, crude protein and gross energy in corn-based diets with a particle size of 1500 compared with 640 μm. Similarly, Lawrence[13] reported greater digestibility of nutrients as particle size was decreased in corn, sorghum and barley-based diets. A reduction in particle size increases the surface area of the grain, allowing for greater interaction with digestive enzymes, which results in an increase in the digestibility of energy and other nutrients contained in the grain[3-5].

Despite the decrease in nutrient digestibility for pigs fed rolled oat diets compared with ground oat diets, there was no difference in the performance of pigs due to the method of processing used. This supports the recommendations of Hancock and Behnke[30], who reported that changes in nutrient digestibility due to processing method are not always accompanied by predictable improvements in pig performance. An explanation for the apparent discrepancy between the digestibility and performance date is the fact that mash diets were fed during the digestibility study while diets were pelleted for the performance trial.

In the present study, having particle sizes ranging from 884 to 1501 μm during the growing period and from 806 to 1250 μm during the finishing period had no significant affect on pig performance. This contrasts with the work of Lawrence (1983) who reported a 12% improvement in feed conversion when the particle size of oats was reduced from >1000 to <600 μm. In addition, Giesemann[29] reported improved efficiency of gain for finishing pigs fed corn and sorghum as particle size was reduced from 1500 to 640 μm. Wondra[5] ground corn to particle sizes ranging from 1000 to 400 μm and reported a 1.3% improvement in feed conversion for every 100 μm decrease in particle size of corn.

The results of the present study indicating no difference in performance between pigs fed normal oat and the low lignin-high fat oat agrees with our previous research[28]. This is not surprising given that the diets were formulated to provide similar levels of nutrients, including energy and amino acids.

Despite the failure of the low lignin-high fat oat to improve pig performance over normal-fat oat, there may still be advantages to its use. It is possible that the use of a high-fat oat could play a role in reducing dust levels in pig barns as Chiba[31] reported significant reductions in aerial dust levels in swine units when diets contained additional lipid. The "prepackaged fat" in high-fat oat may also be of benefit to pig producers who mix their own feed and who may not have sufficient production volume to justify keeping a heated fat tank at their feed mixing facility.

Perhaps the most significant finding of the current experiment was the fact that the performance of pigs fed oats, regardless if normal or high fat, was equal or superior to that of pigs fed barley. Current recommendations regarding the incorporation of oat into rations fed to growing-finishing swine suggest that inclusion should be limited to less than 20%[32,33]. However, these recommendations are based largely on experiments conducted in excess of 25 years ago[34-36].

Considerable improvement has been made in oat varieties during this period, especially in terms of lower % hull (B.G. Rossnagel, Personal Communication, Research Scientist, Crop Development Centre, University of Saskatchewan). The results of the present experiment indicate that both normal and low lignin-high fat oat can substitute for barley at levels as high as 40% of the diet without hindering pig performance. Since the average yield of oat can be equal or higher than barley with lower input costs[37], a re-examination of feeding recommendations regarding oat in swine rations seems warranted.

Another important finding was that fact that pig performance and carcass traits were not affected by processing method. Koch[1] reported that the use of a roller mill to grind grain reduced energy consumption by 30 to 50% compared with a hammer mill. This, taken together with the other advantages of roller mills compared with hammer mills including quieter operation, more exact control of particle size, reduced moisture loss from the grain and lower maintenance costs reported by McEllhiney[8], suggest that there may be some advantage for pig producers to consider roller mills rather than hammer mills for use in processing pig feeds.

CONCLUSION

Feeding a recently developed low lignin-high-fat oat to pigs did not improve growth rate or feed conversion compared with normal-fat oat. Nutrient digestibility and carcass quality were also unaffected by the type of oat fed. However, there appears to be greater potential to utilize oat, regardless of fat level, in rations fed to growing-finishing pigs than is currently being achieved. In addition, there were no differences in performance or carcass traits between pigs fed oats processed using a roller mill compared with a hammer mill suggesting that roller milling may be an attractive alternative to hammer milling as a means to process grain for inclusion in pig diets.

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