Effect of Replacing Wheat or Maize with Micronized Barley on Starter, Grower and Finisher Pig Performance

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ABSTRACT : Two growth performance experiments were undertaken in order to compare the nutritional benefit of micronized dehulled barley (MDB) with wheat and maize. In the first experiment, ninety-six 24 d old Cotswold pigs with an average body weight of 9.5 kg were randomly allotted into one of four dietary treatments. The wheat and MDB ratio in the four complex diets were 100% wheat, 75% wheat+25% MDB, 50% wheat+50% MDB and 100% MDB; cereal was about 47% of the whole diet and varied by using different ratios of wheat and MDB. Starter phase was started at a bodyweight 9.9 kg; grower phase continued at liveweight 37.1 kg and finished at 74.0 kg. The ADFI, ADG and feed efficiency (F/G) were not affected ($p>0.05$) by the level of MDB in the diet from 9.9 to 37.1 kg live weight. However, ADFI was ($p<0.05$) less (14%) for the pigs fed the 75 or 100% of MDB based diets without affecting F/G during the second phase (37.1 to 74.0 kg live weight). Pigs fed the MDB based diet had a lower ($p<0.05$) plasma urea nitrogen (PUN) concentration than the pigs fed the wheat-based diet. In the second experiment, the trial started at 9.9 kg body weight and ended at market weight (107.6 kg), with three different phases in the trial. One hundred and twenty Cotswold pigs were randomly assigned to one of three dietary treatments. The maize and MDB ratio in the three diets were 100% maize, 50% maize+50% MDB and 100% MDB. Diet treatments did not affect ($p>0.05$) growth performance, PUN level, carcass characteristics and organ size, except for an improvement ($p<0.05$) in ADG for the pigs in the starter phase fed 50% and 100% MDB based diets. *(Asian-Aust. J. Anim. Sci. 2001. Vol. 14, No. 5 : 668-676)*

Key Words : Micronization, Dehulled Barley, Wheat, Maize, Pigs

INTRODUCTION

Throughout western Canada millions of pigs are raised annually on barley-based diets. The high crude fibre content is one of the major reasons for its comparably low digestible energy value (Thacker, 1999). Because of its lower digestible energy content, it finds limited use in the diets fed to starter pigs (Aherne and Spicer, 1986). However, when the price of other grains, e.g. maize or wheat are high, it is possible to include high quality barley in starter pig diets, providing a supplement of fat is used (Boychuk, 1997). Barley can be fed very successfully to growing pigs. High-energy cereals such as maize or wheat are often used in combination with barley to maximize growth rate (Hollis and Palmer, 1971). The hull of barley consists of two glumes that completely enclose the seed and has a low digestibility. The concentration of digestible energy in barley should, therefore, be increased when the hull is removed. This should yield a product that is comparable in feeding value to wheat or maize in pig diets. Apart from dehulling processing, a heating process, e.g. extrusion, gamma irradiation, flaking or micronization should also increase the digestible nutrients available to the pigs (McClean, 1993), especially for the weaned pigs and therefore the growth performance will be improved. Micronization is a "short time high temperature" process using humidity, temperature and mechanical pressure to achieve the conditions essential for optimum cooking and starch gelatinisation (Lawrence, 1973a). Many authors reported that the digestibility of nutrients or growth performance was improved by micronization (Lawrence, 1973a, 1973b; Fernandes et al., 1975; Boychuk, 1997; Thacker, 1999). The objectives of the present study were to investigate the effects of replacing wheat and maize with micronized dehulled barley (MDB) on pig growth performance, plasma urea nitrogen (PUN) levels, carcass cut and organ weight.

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MATERIALS AND METHODS

Barley, wheat and maize

One sample respectively of hulled barley, MDB from the same batch of hulled barley, wheat and maize were used in this study. To prepare the MDB, the barley was dehulled, moistened to 22% and micronized on the table of the WestCan Micronizer (Winniepg, Canada) vibrating at a frequency of 1200 million megacycles for 45" at a temperature at 103℃. The three grains were very similar in the concentration of starch, but the GE in MDB was 4 or 5% less than that in wheat or maize. The CP and most AA concentration in wheat were the highest for wheat; maize was the lowest in NDF (table 1).

Experiment 1. Effect of replacing wheat with MDB on starter and grower pig performance

Ninety-six Cotswold pigs, 24 days of age and weighing 9.5 kg body weight (48 gilts and 48 castrates) were randomly allotted to four dietary treatments with a completely randomised design (12 gilts, 12 castrate per treatment). Diets differed by the amount of MDB in the grain portion (47%) of the diet (table 2). The wheat and MDB levels in the four diets were 100% wheat; 75% wheat+25% MDB; 50% wheat+50% MDB. Due to a lower (4%) GE content and less (10%) soybean meal added into the MDB based diets, the usage of the canola oil in the MDB based diets was higher (10%) than that in the wheat based diet. Grains were ground and the complete diet mixed prior to steam-pelleting. All diets were formulated to contain the same levels of lysine, methionine and threonine and to be isocaloric in gross energy. All of the nutrients met or exceeded nutrient requirements for pigs (National Research Council, 1998). Feed was *ad libitum* from self feeders. The pigs were individually housed in a total confinement building in an environmentally controlled room in pens (1.2 m×1.2 m) with totally slatted floor. Individual pig weighs and pen feed intake were determined weekly. Starter diets were fed from 9.9 kg to 37.1 kg body weight and grower diets from 37.1 to 74.0 kg body weight. Water was available free choice for all pigs. Blood samples were taken from all pigs at 60 kg body weight. Feed was removed at 17:00 h the evening prior to the blood collection. Sampling started at 8:00 the following morning. Blood was collected via the jugular vein. Samples were collected in heparinized vacutainer tubes (Becton Dickinson, Rutherford, NJ, USA) and kept on ice during sampling. Within an hour of collecting, tubes were centrifuged and plasma pipetted into vials. These vials were then frozen at 20℃ until analysed for plasma urea nitrogen (PUN).

Table 1. Chemical composition of the micronized dehulled barley (MDB), wheat and maize (% DM basis)

	MDB	Wheat	Maize
GE	17.8	18.6	18.9
Starch	54.3	54.5	55.5
CP	11.1	15.2	9.9
NDF	12.3	12.5	11.8
Essential AA			
Lysine	0.31	0.36	0.31
Threonine	0.30	0.37	0.38
Methionine	0.16	0.19	0.27
Cystine	0.26	0.32	0.22
Arginine	0.40	0.61	0.51
Phenylalanine	0.50	0.69	0.53
Valine	0.31	0.44	0.51
Histidine	0.24	0.60	0.31
Isoleucine	0.24	0.32	0.35
Leucine	0.50	0.81	1.32
Non-essential AA			
Glutamic acid	1.79	3.62	1.38
Glycine	0.33	0.51	0.39
Proline	0.98	1.34	1.14
Tyrosine	0.27	0.35	0.46
Alanine	0.37	0.45	0.45
Aspartic acid	0.55	0.67	0.68
Serine	0.53	0.74	0.53

Experiment 2. Effect of replacing maize with MDB on starter, grower and finisher pig performance

One hundred and twenty Cotswold pigs (60 gilts and 60 castrates) weaned at 24 d of age (9.2 kg body weight) were randomly allotted into three dietary treatments with completely randomised design. Treatment diets differed by the amount of MDB that was included as part of the overall grain portion of the diet (table 3). The maize and MDB ratio in the three diets were 100% maize; 50% maize+50% MDB; 100% MDB. Diet preparation and administration were the same as those of experiment 1. The pigs were fed a starter diet from approximately 9.5 to 23.2 kg live weight, a grower diet from 23.2 to 38.5 kg and a finisher diet from 38.5 kg live weight to 107.6 kg body weight. Water was available free choice for all pigs. All diets met or exceeded the NRC (1998) nutrient requirements. Blood samples were taken from all pigs at 60 kg body weight. Feed was removed at 17:00 h the evening prior to the blood collection. Sampling started at 8:00 the following morning. Blood was collected via the jugular vein. Samples were collected in heparinized vacutainer tubes (Becton Dickinson, Rutherford, NJ) and kept on ice during sampling. Within an hour of collecting, tubes were centrifuged and plasma pipetted into vials. These vials were then frozen at 20℃ until analysed for PUN. Upon termination of the experiments, 24 pigs, 8 from each treatment were randomly selected for carcass evaluation. The slaughter pigs were humanely killed (electrically stunned followed by exsanguination), dehaired and eviscerated. The head was removed, and the carcass was split longitudinally. The hot carcass was weighed, chilled at 1℃ for 48 h, and carcass measurements were taken. The evaluation at market included the weights of half carcass, head, loin+belly, shoulder, picnic, butt, hock, trim, fat trimmings, spareribs, leg, riblets, back fat, liver, stomach, small intestine and large intestine.

Blood sampling

All of the pigs from the two experiments were

Table 2. Composition of the starter and grower diets for pigs fed various concentrations of micronized dehulled barley (MDB) and wheat (W)

W/MDB ratio	100%W		75% W+25% MDB		50% W+50% MDB		100% MDB	
Level of MDB (%)	-		12.25		23.55		47.15	
	Starter	Grower	Starter	Grower	Starter	Grower	Starter	Grower
Ingredients (% as fed basis)								
Wheat	47.30	61.98	35.04	46.52	23.55	31.00	-	-
Micronized barley	-	-	12.25	15.50	23.55	31.00	47.15	61.90
Hulled barley	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Soybean meal	16.3	15.00	16.00	14.60	16.00	14.30	15.50	13.91
Canola oil	3.7	3.70	4.00	4.00	4.20	4.30	4.60	4.70
Constant[1]	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28
L-lysine (HCL)	0.25	0.26	0.24	0.28	0.23	0.29	0.25	0.32
Methionine	0.08	0.08	0.10	0.10	0.10	0.11	0.12	0.15
Threonine	0.19	0.20	0.19	0.22	0.19	0.22	0.20	0.24
Whey	13.40	-	13.40	-	13.40	-	13.4	-
Herring meal	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Chemical Analysis (% as fed basis)								
CP	19.8	17.9	19.5	17.8	19.4	17.8	19.4	17.7
DM	96.6	98.0	95.4	98.0	92.9	98.1	90.4	96.0
DE (MJ kg^{-1})	16.02	15.56	16.02	15.57	16.02	15.57	16.02	15.57
Ether extract	7.8	7.0	6.9	6.1	7.2	6.8	9.1	8.7
NDF	8.7	10.5	8.6	8.6	8.0	8.9	7.5	7.6
Lysine	1.3	1.2	1.3	1.2	1.3	1.2	1.3	1.2
Methionine	0.5	0.4	0.5	0.4	0.5	0.4	0.5	0.4
Cystine	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Threonine	0.9	0.8	0.9	0.8	0.9	0.8	0.9	0.8

[1] Constant components per kg of diet: limestone 12 g/kg; dicalcium phosphate 18 g/kg; iodized salt 2.8 g/kg and premix 20 g/kg. Premix provided the following per kg of diet: 130 mg zinc, 68 mg manganese, 165 mg iron, 140 mg copper, 1.9 mg iodine, 0.25 mg selenium, 280 mg choline chloride, 11445 Iμ vitamin D_3, 100 Iμ vitamin E, 2.3 mg vitamin K, 6 mg riboflavin, 23.5 mg niacin, 185 mg biotin, 18 mg calcium pantothenate, 0.46 mg vitamin B_{12}.

prepared for blood sampling. Feed was removed at 17:00 h the evening prior to the blood collection. Sampling started at 8:00 the following morning. Blood was collected via the jugular vein at approximately 60 kg live weight. Samples were collected in heparinized vacutainer tubes (Becton Dickinson, Rutherford, NJ, USA) and kept on ice during sampling. Within an hour of collecting, tubes were centrifuged and plasma pipetted into vials. These vials were then frozen at 20℃ until analysed for PUN.

Digestibility trial

Fecal digestibility of energy and ileal digestibilites of starch, CP and AA in the 100% wheat, 100% MDB and 100% maize based diets for the starter stage which were used in experiment 1 and 2 were determined using four castrates per treatment starting at an average body weight of 15.1 kg. To these diets was added 0.2% chromic oxide as a digestibility marker. At the same time, a dehulled barley based diet which with the same proportions and same ingredients as the 100% MDB based diet was determined as a control for the MDB based diet. The pigs were surgically fitted with a post-valve "T" cecum cannula (PVTC) accruing to Van Leeuwen et al. (1991) and modified by Yin (1997). The pigs were housed individually in a metabolism cage. The marked feed was provided for a 7-d acclimatization period, followed by a 5-d fecal collection and 2-d ileal digesta collection. The fecal and ileal digesta were frozen for storage. Prior to analysis, the samples were freeze-dried.

Chemical analysis

Feed samples were collected at random intervals during the experiment, and stored. Prior to analysis, samples were mixed and ground in a Tecator cyclotec 1093 sample MW (Hoganas, Sweden). Samples were dried in a convection oven at 105℃ for 24 h to determine dry matter content. Crude protein, gross energy, dry matter and neutral detergent fibre of the feeds were determined according to the AOAC (1986).

Table 3. Composition of the starter, grower and finisher diets for pigs fed various of micronized dehulled barley (MDB) and maize (M)

M/MDB ratio	100% M			50% M+50% MDB			100% MDB		
Level of MDB (%)	0	0	0	25.8	33.3	34.8	57.8	66.9	69.9
	Starter	Grower	Finisher	Starter	Grower	Finisher	Starter	Grower	Finisher
Ingredients (% as fed basis)									
Maize	53.26	66.71	68.00	25.80	33.34	34.07	-	-	-
MDB	-	-	-	25.80	33.34	34.07	51.80	66.70	69.85
Soybean meal	22.50	22.50	22.88	22.26	21.70	21.59	21.38	20.70	19.00
Canola oil	1.85	1.85	1.85	3.50	2.70	2.80	4.20	3.65	3.65
Constant[1]	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28	5.28
L-Lysine (HCl) (81%)	0.09	0.09	0.09	0.17	0.09	0.09	0.15	0.09	0.09
DL-Methionine (98%)	0.07	0.07	0.10	0.13	0.02	0.06	0.09	-	0.03
L-Threonine (98%)	-	-	-	0.11	0.03	0.04	0.15	0.08	0.10
Herring meal	3.50	3.50	2.00	3.50	3.50	2.00	3.50	3.50	2.00
Milk products	13.45	-	-	13.45	-	-	13.45	-	-
Chemical analysis (% as fed basis)									
CP	21.1	18.6	17.5	21.3	18.6	17.5	21.2	18.6	17.5
DM	91.1	89.6	96.2	91.1	90.2	98.7	91.1	91.1	94.1
DE (MJ kg^{-1})	16.34	15.90	15.90	16.34	15.90	15.91	15.89	15.91	15.92
Lysine	1.3	1.1	1.0	1.4	1.1	1.0	1.3	1.1	1.0
Methionine	0.4	0.4	0.3	0.4	0.4	0.3	0.4	0.4	0.3
Cystine	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.3	0.3
Threonine	0.9	0.8	0.7	0.9	0.7	0.7	0.9	0.7	0.7

[1] Constant components per kg of diet: limestone 12 g/kg; dicalcium phosphate 18 g/kg; iodized salt 2.8 g/kg and premix 20 g/kg. Premix provided the following per kg of diet: 130 mg zinc, 68 mg manganese, 165 mg iron, 140 mg copper, 0.9 mg iodine, 0.25 mg selenium, 280 mg choline chloride, 11445 Iμ vitamin A, 1700 Iμ vitamin D_3, 100 Iμ vitamin E, 2.3 mg vitamin K, 6 mg riboflavin, 23.5 mg niacin, 18.5 mg biotin, 18 mg calcium pantothenate, 0.46 mg vitamin B_{12}.

Starch was determined by the method of Technicon (1978). Gross energy was determined by using an adiabatic oxygen bomb calorimeter (Parr, model 1241). For amino acids analysis, samples were hydrolysed at 110℃ in an N atmosphere for 20 min. The amino acids of hydrolyzates were then separated by HPLC using an ion-exchange column and lithium buffers as eluants. Amino acids were detected and measured fluorometrically using *o*-phthaldehyde post-column derivatization (Benson and Hare, 1975). Norleucine was used as an internal standard. For analysis of sulphur amino acids, samples were oxidised before hydrolysis using the procedure described by Moor (1963). Methionine was oxidised to methionine sulfone and cystine to cysteic acid. These amino acids were then determined by the same procedure as monoxidized hydrolyzates. Plasma samples were analysed for urea nitrogen concentrations using a standard kit (Procedure No. 535) firm Sigma Diagnostics (St. Louis, MO, USA). Viscosity was determined according to the method of Veldman and Vahl (1994).

Statistical analysis

The ADG, ADFI, feed/Gain (F/G), PUN, and Carcass data were analysed by analysis of variance using GLM in the Statistical Analysis System (SAS Institute Inc., 1989). The model used for average daily feed intake and feed efficiency was $Y_{ijk}=\mu+t_i+s_j+r_j+ts_{ij}+e_{ijk}$, where Y_{ijk}=the average daily gain per pig on the i^{th} diet in the j^{th} sex within the k^{th} room, μ=the overall mean, t_i=the effect of the i^{th} treatment, s_j=the effect of the j^{th} sex, r_j=the effect of the k^{th} room, ts_{ij}=the effect of the interaction of the i^{th} treatment and the j^{th} sex, e_{ijk}=random error. Data from the digestibility trial were analysed with the ANOVA procedures of the Statistical Analysis System (SAS Institute Inc., 1989).

RESULTS

Experiment 1

The results of ADG, ADFI, feed/gain (F/G) and PUN levels of the starter and grower pigs fed various concentrations of MDB and wheat are presented in table 4. There were no differences ($p>0.05$) in growth performance, except for a significant reduction ($p<0.05$) in ADFI with the 100% MDB based diet. There was a sex effect ($p<0.05$) with castrates having a higher ADG than the gilts in all phases and a lower ADFI in the grower phase (table 5). The ADG for the castrates on average across treatments at the starter

Table 4. Growth performance and plasma urea nitrogen (PUN) levels (mg/dl) of the starter and grower pigs fed various concentrations of micronized dehulled barley (MDB) and wheat (W)

W/MDB ratio	100W	75% W+ 25%MDA	50% W+ 50% MDB	100% MDB		
Level of MDB (%)	0	12.25	23.55	47.15	SEM[1]	p=
Starter phase (9.9~37.1 kg)						
Start wt[2] (kg)	9.8	9.9	9.8	10.0		
Finish wt (kg)	36.5	37.6	37.1	37.2		
ADG[3] (kg)	0.678	0.669	0.667	0.640	0.021	0.14
ADFI[4] (kg)	1.100	1.010	1.010	9.801	0.033	0.09
F/G[5]	1.62	1.51	1.51	1.53	0.04	0.13
Grower phase (37.1~74.0 kg)						
Start wt (kg)	36.5	37.6	37.1	37.2		
Finish wt (kg)	73.1	74.4	77.3	71.0		
ADG (kg)	925	914	930	879	0.020	0.11
ADFI (kg)	2.179[a]	2.022[b]	2.220[a]	1.901[b]	0.051	0.05
F/G	2.36	2.22	2.39	2.19	0.08	0.09
PUN (mg/dl) (at 60 kg wt)	24.42[a]	19.79[a]	19.89[a]	15.15[b]	1.53	0.03

[1] Pooled standard error of means. [2] wt=weight. [3] Average daily again. [4] average daily feed intake. [5] Feed conversion rate. [a,b] Values in the same row without a common superscript are significantly different ($p<0.05$).

Table 5. Growth performance of male (m) and female (f) starter and grower pigs fed various concentrations of micronized dehulled barley (MDB) and wheat (W)

W/MDB	100W		75%+ 25% MDB		50% W+ 50% MDB		100% MDB			
Level of MDB (%)	0		12.25		23.55		47.15			
Sex	m	f	m	f	m	f	m	f	SEM[1]	p=
Starter phase (9.9-7.1 kg)										
Start wt[2] (kg)	10.2	9.35	9.32	10.52	9.65	9.88	9.93	10.07		
Finish wt (kg)	37.2	35.7	38.3	37.0	37.3	36.9	37.6	36.8		
ADG (kg)[3]	0.698	0.658	0.687	0.651	0.705	0.630	0.657	0.623	0.030	0.04
ADFI (kg)[4]	1.062	1.131	1.038	0.981	1.056	0.960	1.023	0.936	0.042	0.11
F/G[5]	1.52	1.72	1.51	1.51	1.50	1.52	1.56	1.50	0.06	0.09
Grower phase (37.1-74.0 kg)										
Start wt (kg)	37.2	35.7	38.3	37	37.3	36.9	37.6	36.8		
Finish wt (kg)	74.6	71.5	76.2	72.5	83.0	71.6	72.3	69.6		
ADG (kg)	0.956	0.893	0.957	0.870	0.992	0.867	0.934	0.824	0.043	0.01
ADFI (kg)	2.297	2.062	2.176	1.868	2.365	2.075	2.028	1.779	0.083	0.01
F/G	2.41	2.31	2.27	2.16	2.38	2.40	2.18	2.18	0.13	0.12

[1] Pooled standard error of means. [2] wt=weight. [3] Average daily gain. [4] average daily feed intake. [5] Feed conversation rate.

phase and grower was 687, 960 g and for gilts only 640, 863 g. The ADFI for castrates on average across treatments at the starter phase and grower was 1045, 2217 g and for gilts only 1002, 1946 g. However, there was no sex×MDB interaction. PUN is often used to determine the efficiency of nitrogen utilization. A reduction in PUN concentration reflects a decrease in urea synthesis and therefore more efficient utilization of amino acids (Coma et al., 1995). The PUN levels of the pigs measured at 60 kg live weight indicated that pigs fed MDB based diet had a lower PUN concentration ($p<0.01$) compared to those fed the wheat-based diet. There appeared to be a reciprocal relationship between the inclusion levels of MDB in the diet and the corresponding PUN concentration. This suggests that the protein in the MDB may be more available to the pigs than the protein in the wheat based diet.

Experiment 2

Diet treatments did not affect ($p>0.05$) growth performance and PUN levels in any phase, except for the ADG in the starter phase (table 6). ADG of pigs in the starter phase was improved ($p<0.01$) with the

Table 6. Performance of starter, grower and finisher pigs and plasma urea nitrogen (PUN) levels (mg/dl) fed various concentrations of micronized dehulled barley (MDB) and maize (M)

M/MDB ratio	100% M	50% M+50 MDB	100% MDB	SEM[1]	p=
Level of MDB (%)	0	25.8	57.8		
Starter phase (9.5~23.2 kg)					
Start wt[2] (kg)	9.5	9.5	9.6		
Finish wt (kg)	21.6	24.1	24.0		
ADG[3] (kg)	0.398[a]	0.481[b]	0.474[b]	0.020	0.04
ADFI[4] (kg)	0.570	0.584	0.639	0.053	0.19
F/G[5]	1.43	1.22	1.35	0.08	0.28
Grower phase (23.2~38.5 kg)					
Start wt (kg)	21.6	24.1	24.0		
Finish wt (kg)	38.6	38.1	38.7		
ADG (kg)	0.962	0.897	0.913	0.083	0.23
ADFI (kg)	1.250	1.320	1.350	0.014	0.19
F/G	1.30	1.51	1.5	0.11	0.16
Finisher phase (38.5~107.6 kg)					
Start wt (kg)	38.6	38.1	38.7		
Finish wt (kg)	106.2	107.6	109.1		
ADG (kg)	1.020	1.021	1.020	0.028	0.99
ADFI (kg)	3.093	3.092	3.310	0.018	0.83
F/G	2.94	3.03	3.13	0.11	0.45
Overall performance					
Start wt (kg)	9.43	9.37	9.59		
Finish wt (kg)	106.2	107.6	109.1		
ADG (kg)	0.845	0.858	0.859	0.011	0.20
ADFI (kg)	2.115	2.123	2.286	0.050	0.12
F/G	2.50	2.47	2.56	0.16	0.10
PUN (mg/dl) (at 60 kg wt)	16.2	15.9	17.4	0.49	0.08

[1] Pooled standard error of means. [2] wt=weight. [3] Average daily gain. [4] Average daily feed intake. [5] Feed conversion rate.
[a,b] Values in the same row without a common superscript are significantly different ($p<0.05$).

replacement of 50 and 100% of maize with MDB. Similar to the results of experiment 1, there was a sex effect with castrates having a higher ADG but a lower ADFI than the gilts in all phases (table 7). The ADG for castrates on average across treatments at the starter, grower and finisher phases was 470, 957, 1062 g and for gilts only 431, 890, 979 g, respectively. The ADFI for castrates on average across treatments at the starter, grower and finisher phases was 621, 1335, 3359 g and for gilts only 574, 1297, 2972 g. There was no sex×MDB interaction. The slaughter evaluation by the weights of different meat cuts and of organ, showed that diet treatments did not affect ($p>0.05$) the carcass characteristics and organ weight of the grower finisher pigs (table 8).

DISCUSSION

Lawrence (1973a) reported a 4 percent improvement in feed conversion efficiency of pigs fed MDB over pigs fed a wheat diet from 17 to 50 kg live weight. Lawrence (1973b) found a 3.5 percent ADG improvement for pigs fed a MDB based diet from 22 to 50 kg live weight, compared with a wheat-based diet. The results of the present study suggest that the wheat or maize in the starter, grower and finisher pig diets can be replaced partly or totally by MDB without affecting performance. Importantly, the ADG was increased ($p<0.05$) by 21 and 19% for the pigs at the starter phase fed the 50 and 100% MDB diets compared with the maize based diet.

Digestibility of starch is affected by many factors such as the weight of the pigs, and the amylopectin content and physical form of the starch. The digestion of raw starch by newborn pigs is restricted by the structure of the starch granule and, because of insufficient production of enzymes such as amylase, the accessibility of the starch granules by enzymes is reduced (Kidder and Manners, 1978). For starch to be easily accessed by enzymes, starch can be modified by micronization, which results in changes in its gelatinization. Gelatinization occurs when starch absorbs water and heat is applied (60-80℃). Gelatinization of starch makes the starch accessible by

Table 7. Growth performance of male (m) and female (f) starter, grower and finisher pigs fed various concentrations of micronized dehulled barley (MDB) and Maize (M)

M/MDB ratio	100% M		50% M+50% MDB		100% MDB		SEM[1]	p=
Level of MDB (%)	0		25.8		57.8			
Sex	m	f	m	f	m	f		
Starter phase (9.5~23.2 kg)								
Start wt[2] (kg)	9.45	9.48	9.50	9.48	9.70	9.49		
Finish wt (kg)	22.5	20.7	25.2	22.9	23.9	24.1		
ADG[3] (kg)	0.428	0.369	0.517	0.444	0.465	0.482	0.030	0.04
ADFI[4] (kg)	0.627	0.513	0.582	0.587	0.55	0.623	0.070	0.11
F/G[5]	1.46	1.39	1.13	1.32	1.41	1.30	0.12	0.08
Grower phase (23.2~38.5 kg)								
Start wt (kg)	22.5	20.7	25.2	22.9	23.9	24.1		
Finish wt (kg)	41.7	36.1	40.4	40.1	41.2	39.7	0.110	0.01
ADG (kg)	1.067	0.856	0.844	0.950	0.960	0.865	0.020	0.09
ADFI (kg)	1.379	1.180	1.319	1.320	1.306	1.391	0.16	0.07
F/G	1.30	1.30	1.61	1.40	1.37	1.62		
Finisher phase (38~107.6 kg)								
Statr wt (kg)	41.7	36.1	40.4	40.1	41.2	39.7		
Finish wt (kg)	108.1	105.0	107.9	107.4	109.5	108.9		
ADG (kg)	1.066	0.974	1.054	0.989	1.065	0.976	0.10	0.01
ADFI (kg)	3.426	2.761	3.208	2.976	3.442	3.178	0.250	0.14
F/G	3.18	2.83	3.01	2.98	3.20	3.24	0.15	0.08

[1] Pooled standard error of means. [2] wt=weight. [3] Average daily gain. [4] average daily feed intake. [5] Feed conversion rate.

Table 8. Slaughter evaluation of finisher pigs fed various concentrations of micronized dehulled barley (MDB) and maize (M)

M/MDB ratio	100% M	50% M+50% MDB	100% MDB	SEM[1]	p=
Level of MDB (%)	0	25.8	57.8		
Live weight (kg)	106.8	107.0	107.7	1.10	0.35
Half carcass (kg)	42.7	43.0	43.1	0.75	0.12
Head (kg)	3.4	3.4	3.2	0.16	0.23
Loin+belly (kg)	11.7	11.9	12.3	0.26	0.99
Shoulder (kg)	11.6	11.4	11.7	0.56	0.20
Picnic (kg)	4.0	3.6	3.4	0.23	0.09
Butt (kg)	4.1	3.9	4.2	0.25	0.10
Hock (kg)	1.5	1.4	1.4	0.11	0.26
Leg (kg)	9.9	11.2	9.4	0.83	0.07
Trim (kg)	1.0	1.3	1.3	0.32	0.15
Fat trimmings (kg)	3.9	3.3	4.1	0.56	0.09
Back fat 1[2] (kg)	2.1	2.5	2.2	0.31	0.10
Back fat 2 (kg)	2.3	1.9	2.5	0.44	0.09
Back fat 3 (kg)	1.6	1.9	2.4	0.38	0.08
Back fat 4 (kg)	1.7	1.5	2.7	0.41	0.07
Liver (kg)	1.54	1.58	1.55	0.19	0.23
Stomach (kg)	0.56	0.53	0.63	0.09	0.19
Small intestine (kg)	2.73	2.54	2.51	0.45	0.11
Large intestine (kg)	2.71	2.47	2.56	0.56	0.23

[1] Pooled standard error of the means. [2] Taken from four different locations on the back.

amylase. This will increase the digestibility of the starch by the young pig, and improves growth performance.

Thacker (1999) reported that micronization increased the percentage of gelatinized starch in both grower and the finisher pig diets. According to Hauck et al. (1994), gelatinization is defined as the irreversible destruction of the crystalline order in a starch granule so that the surface of every molecule is made accessible to solvents or reactants. Gelatinization enhances the ability of starches to absorb large quantities of water this increased water holding capacity is suggested to lead to improved digestibility (Hauck et al., 1994). Thacker (1999) observed that for the hulless barley diets, micronization increased the percentage of gelatinized starch from 10.9% to 32.9% for the grower diets and from 16.3% to 52.2% for the finisher diets. For the hulless barley diets, micronization increased the percentage of gelatinization starch from 11.9% to 23.1% for the grower diets and from 13.3 to 30.3% for the finisher diets.

A significant improvement in the digestibility of CP and GE for pigs by micronization of barley has been reported by many authors. Fernandes et al. (1975) reported a 6.2% increase in fecal digestibility of protein and a 3.7% increase in overall digestibility of energy. Similarly, Thacker (1999) reported that the fecal digestibility of CP and GE in barley diet was increased by 8 and 4.4% respectively by micronization. Boychuk (1997) found that the ileal digestibility of starch in an MDB based diet was increased ($p<0.01$) by micronization. Similar to the previous studies, the results from the present study show that the starch digestibility in the small intestine was increased ($p<0.05$) by micronization (table 9). Although micronization did not increase the ileal digestibility of CP and AA, the digested AA in the MDB based diet might be more available for protein deposition than that in the wheat-based diet. This can be explained by a lower (61%) PUN level for the pigs fed 100% MDB based diet than that for the pigs fed the 100% wheat based diet.

Table 9. Fecal apparent digestibility (%) of GE and ileal apparent digestibilities of starch, CP and AA of the micronized dehulled barley (MDB), dehulled barley, wheat and maize based diets

	MDB	Dehulled barley	Wheat	Maize	SEM[1]
GE	77.5[a]	70.1[b]	75.9[a]	77.0[a]	1.88
Starch	91.8[a]	84.0[b]	85.2[b]	86.4[b]	2.92
CP	72.9	70.3	73.4	74.3	2.08
Essential AA					
Lysine	74.1	73.3	75.1	75.6	2.01
Threonine	68.5	65.9	70.2	69.0	1.98
Methionine	76.3	75.5	77.0	77.2	2.31
Cystine	76.0	74.6	75.6	75.8	1.58
Arginine	86.5	84.0	86.3	88.0	2.01
Phenylalanine	77.7	75.9	78.0	76.5	1.99
Valine	68.8	67.4	67.8	68.0	2.00
Histidine	79.9	78.0	78.9	80.2	1.58
Isoleucine	74.4	73.3	75.3	74.6	1.69
Leucine	76.6	75.6	75.0	75.9	2.03
Non-essential AA					
Glutamic acid	77.9	77.0	76.9	77.0	2.30
Glycine	70.6	69.0	71.0	71.2	2.00
Proline	66.8	64.2	65.9	67.0	1.96
Tyrosine	75.5	74.9	74.9	75.0	2.08
Alanine	63.9	62.0	62.9	64.0	2.09
Aspartic acid	68.9	67.9	69.9	69.2	1.97
Serine	74.9	73.6	73.6	75.0	2.00

[1] Pooled standard error of the means.

[a,b] Values in the same row without a common supscript are significantly different ($p<0.05$).

Similarly to the results of Fernandes et al. (1975), the results of this study show that micronization of the dehulled barley did not influence ($p>0.05$) the carcass characteristics of growing pigs. There was only a numerical increase in the stomach weight (11%) of the pigs fed 100% MDB based diet compared to the maize-based diet. Thacker (1999) reported that one of the problems of using micronization barley for pig feeding was that the feed intake of pigs was reduced by micronization. The author explained this by the observed increase in meal viscosity. However, only one significantly reduced feed intake was observed in this study for the pigs in growing phase fed the 100% MDB based diet compared with 100% of wheat based diet, and the daily gain and feed efficiency were not affected.

IMPLICATIONS

The physico-chemical properties, digestibility and performance data suggest that wheat or maize could be partly or total exchanged by micronized dehulled barley for starter, grower or finisher pig production.

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