Effect of grain type, particle size and processing condition on growth performance characteristics in pigs

1B-113

Report prepared for the

Co-operative Research Centre for an Internationally Competitive Pork Industry

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Executive Summary

Productivity and profitability of the pig industry is affected greatly by the efficiency of use of cereal grains, which comprise greater than 60 percent of most pig diets. Grain particles that escape digestion in the small intestines and are fermented in the hind-gut reduce the amount of energy available to the pig because approximately 15% of the fermented energy is lost as heat of fermentation and methane. Research within the Pork CRC project 1B-101 showed that 2-4 MJ/kg energy from cereal grains can be digested in the hind-gut. Additional research in project 1B-102 illustrated that undigested starch, protein and cell wall components of cereal grains at the end of the small intestine existed primarily as larger particles. The research showed also that enzyme diffusion rates decrease with the inverse square of particle size, with a 2-fold increase in particle size decreasing enzyme diffusion rate and rate of digestion 4-fold. Diffusion rate of enzymes in barley particles was found to be approximately twice as fast as enzyme diffusion rate in sorghum particles of the same size. Other research in project 1B-102 had shown that rate of starch digestion was also increased when the starch was partially gelatinized through the application of moist heat.

Conventional hammer milling of grains results in a significant proportion of large particles. Thus, an experiment was conducted to investigate the effect of regrinding large particles (>1.8 mm for barley and > 0.9 mm for sorghum) and returning them to the initially ground proportion. This resulted in a reduction in large particles, but little increase in the proportion of small particles.

Re-ground and single grind samples of sorghum and barley were incorporated into a standard grower diet with grain representing 72% of the feed. Diets were fed either as a mash or after steam pelleting under typical commercial conditions. The diets were offered to young male weaner pigs at Rivalea or grower pigs at Wacol, Queensland.

Re-grinding to remove the large particles significantly reduced the intake of the sorghum based mash diets with little effect on growth rate for both the weaner and grower pigs. Consequently, there was a substantial improvement in feed conversion efficiency. Effects were particularly marked for mash feeds with re-grinding resulting in 22% and 10.5% improvement in the efficiency of feed use for sorghum offered, respectively, to weaner and grower pigs. Similarly re-grinding of barley fed as a mash resulted in 15% and 8.3% improvement in efficiency of feed use for weaner and grower pigs, respectively. Re-grinding of either sorghum or barley offered as a mash resulted in a lower FCR than pelleting grain based diets after a single grind.

The experiments show that there are large effects of reducing the size of large particles on the efficiency of feed use by young pigs offered either barley or sorghum based diets. These results are particularly important for pig enterprises offering mash feeds because removal of the large particles resulted in numerically better feed conversion efficiency than traditional milling and pelleting of the diets. Nevertheless, pelleting of diets containing conventionally milled grain resulted in significant improvements in feed conversion efficiency compared with mash diets for all comparisons except barley based diets fed to grower pigs.

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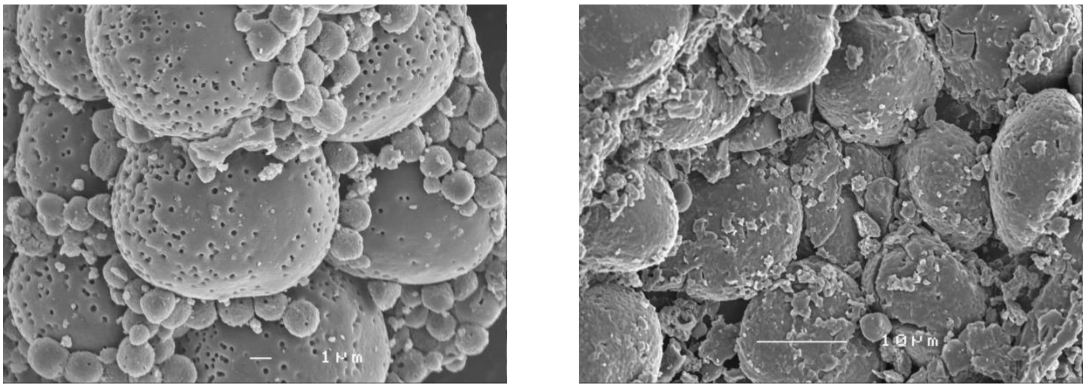
1. Introduction

Research within subprogram 1B has shown that between 2 and 4 MJ/kg of energy in cereal grains is not digested in the small intestines, but fermented by microorganisms in the hind-gut with up to 15 percent of that energy being lost from the pig as heat of fermentation and methane. The results show that the undigested starch, protein and cell wall fractions at the end of the small intestine tend to exist as large particles. There is also good evidence that the presence of undigested nutrients at the end of the small intestine induces the ‘ileal or intestinal brake’ which slows the rate of passage of digesta through the intestines and limits the amount of feed eaten through the direct actions of peptides released from the ileum and colon on the feeding centres of the brain.



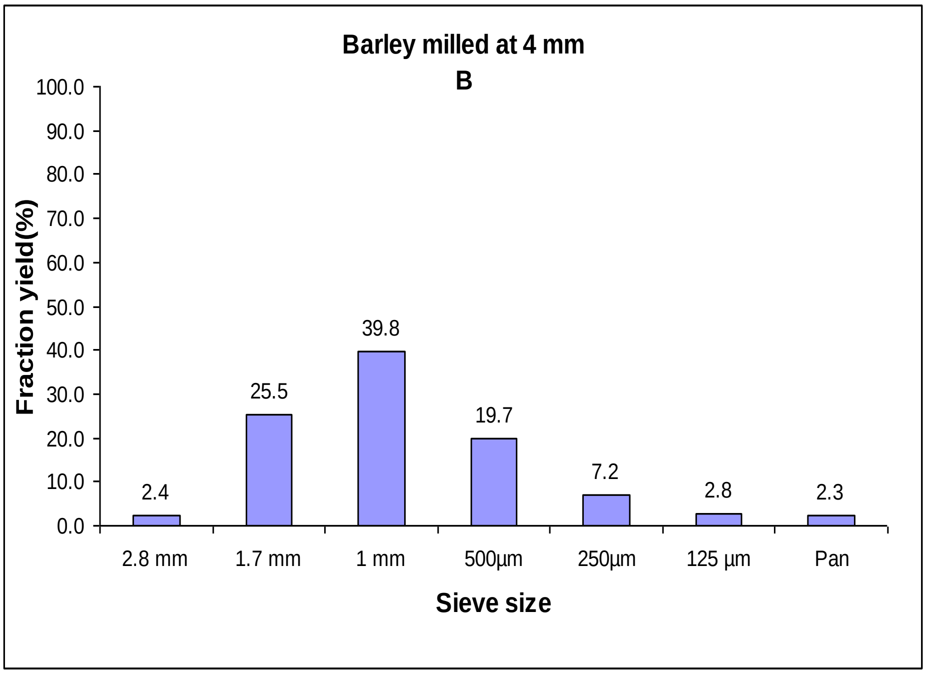
(a) (b)

Figure 1 - Scanning electron microscope images of particles of sorghum (a) and barley (b) grains recovered from the ileum of pigs.

Figure 1 shows scanning electron microscope images of the surfaces of (a) sorghum and (b) barley particulates recovered from the ileum of pigs. Undigested feed at the ileum was composed of grain particulates containing both starch granules (10-15 µm) and protein bodies (1-2 µm), together with separate ‘fibre’ particles that did not contain starch granules or protein bodies. The ‘pinholes’ observed for sorghum and the roughened surfaces of barley particles are characteristic of partial enzymic digestion of both starch and protein, and suggest that starch and protein are digested essentially in parallel.

Processing techniques that reduce the size of grain particles should therefore increase the rate of digestion in the upper sections of the small intestines and thereby increase both the energy available to the animal as feed passes through the intestines and the amount of feed eaten. These effects are particularly important for sorghum based diets where energy intake has been found to be at least 10 percent less than for similarly formulated diets based on wheat.

Conventional milling processes produce a range of particle sizes as separated by sieving (Figure 2). Separation of milled fractions into discrete particle size fractions showed a dramatic effect of particle size on in vitro digestibility for both barley and sorghum (Figure 3). The Figure suggests that particles of 1 mm (barley) or 0.5 mm (sorghum) or over are digested considerably more slowly than smaller particles. More detailed analysis of digestion profiles (Final Report 1B-102) showed that the rate coefficient for enzyme diffusion was proportional to the inverse square of the particle size. Thus, doubling the particle size results in a quarter of the enzyme digestion rate. This explains why there is such a wide difference in digestion rates (Figure 3) for different particle size fractions. The rate of enzyme diffusion was also shown to be approximately twice as fast for barley as it was for sorghum particles of the same size. Further research showed grain particles arriving at the end of the small intestines were approximately 1 mm for barley based diets and 0.75 mm for sorghum based diets. This information suggested that if grain particles in the feed did not exceed 1.0 mm for barley and 0.75 for sorghum, all starch should be digested in the small intestines and both feed intake and the efficiency of feed use should be improved.



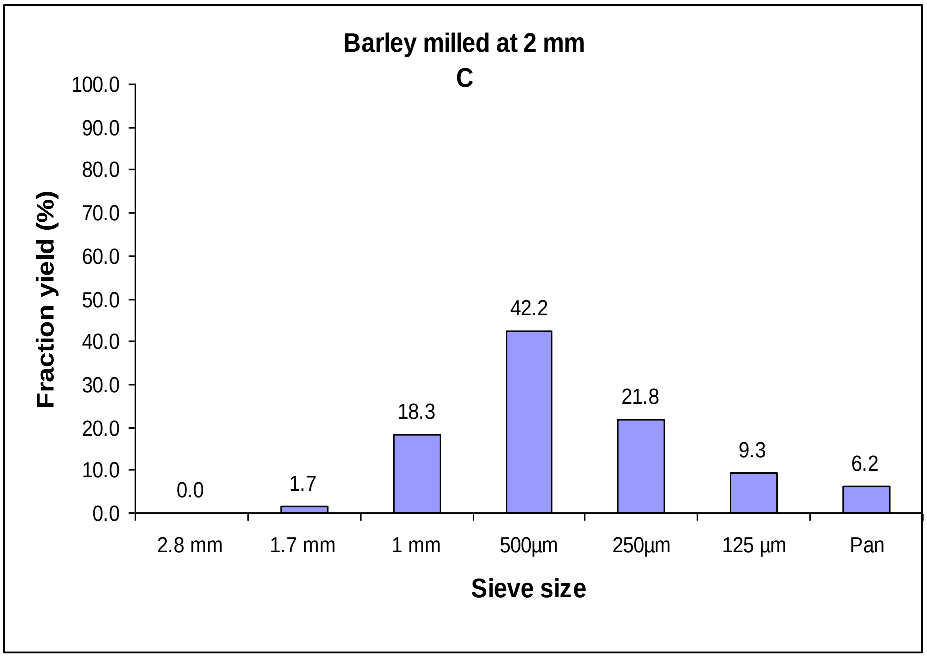
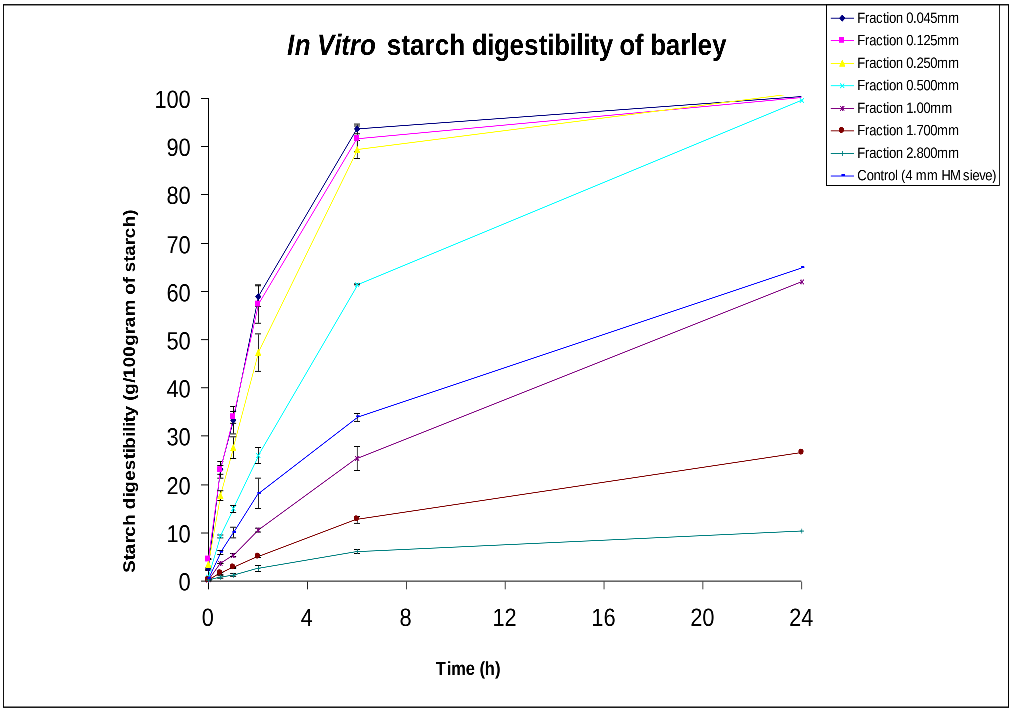


Figure 2 - Sieving analysis of barley milled through a 4 mm or 2mm screen.



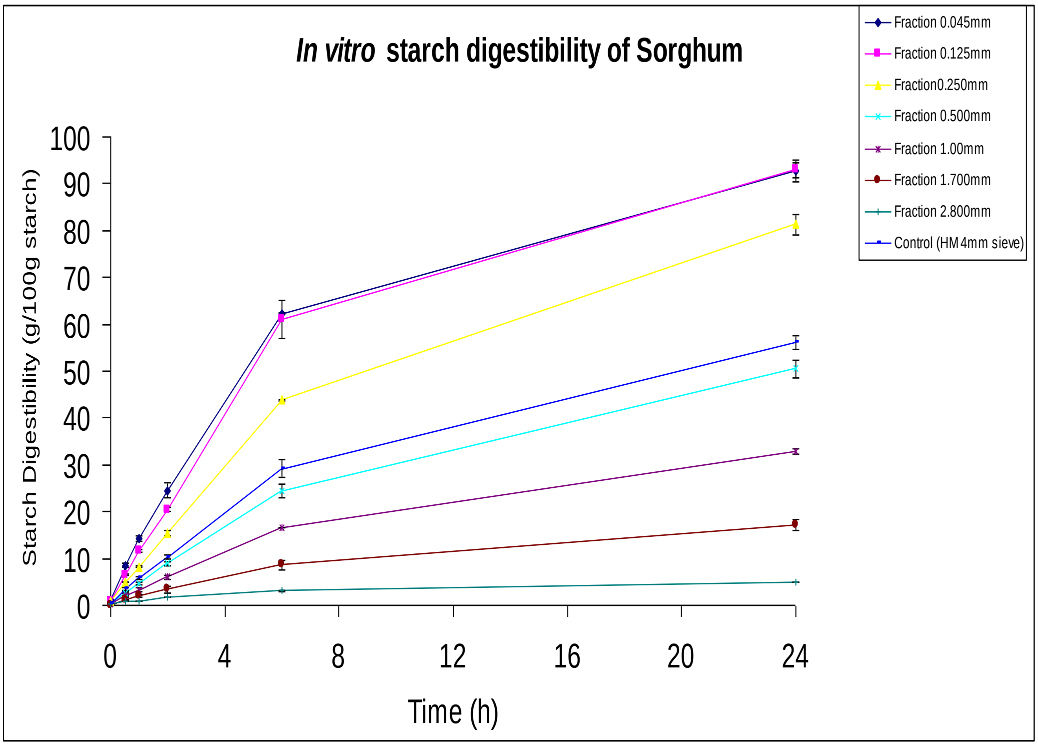


Figure 3 - Effect of sieve fractions compared with non-fractionated controls on in vitro starch digestibility from milled grains.

Project 1B-113 was established to demonstrate that the observations of reduced digestibility of starch in large particles obtained in vitro also apply in vivo. Two experiments, one with weaner and one with grower pigs, were conducted to test the hypothesis that removal of large grain particles from barley and sorghum based diets should improve feed intake and the efficiency of feed use by pigs. Research within project 1B-102 had shown that, in addition to particle size, the extent of gelatinisation of the starch within cereal grain diets also influenced the rate of in vitro starch digestion. Consequently, the experiment examined the effects of particle size distribution on the performance of pigs offered both mash and steam pelleted diets. Steam pelleting is known to increase gelatinisation of starch in cereal grains.

2. Methodology

Diet preparation

Samples were obtained for animal performance trials, in collaboration with the stockfeed manufacturer, Better Blend, by (a) grinding each of sorghum and barley through a 4 mm hammer mill screen, (b) sieving the resultant material through a 1.8 mm (barley) or 0.9 mm (sorghum) sieve using a seed cleaner machine, (c) regrinding the captured particles through a 3.2 mm hammer mill screen, and adding these back to the particles that passed through the sieve after a first grind. This material is referred to as re-ground. A smaller sieve was selected for fractionating milled sorghum based on the slower rates of enzyme digestion compared with barley at the same particle size. Figure 4 shows that re-grinding removed nearly all particles larger than 1.7 mm without generating many additional particles smaller than 0.125 mm.

Re-ground and single grind samples of sorghum and barley were incorporated into a standard grower diet with grain representing 72% of the feed. Diets were fed either as a mash or after steam pelleting under typical commercial conditions. The diets were offered to young male weaner pigs at Rivalea or grower pigs at Wacol, Queensland.

Animal studies

The studies were a 2 x 2 x 2 design with barley vs. sorghum, single grind vs. re-ground, and mash vs. pelleted as variables. In the Rivalea experiment, 20 pigs, 28 days of age were selected per treatment. Each pig was given a 5 day acclimatisation period and feed intake and growth rate were measured over the following 21 days. In the Wacol experiment, 12 pigs per treatment were selected in a randomized complete block design. The initial weight of the pigs was approximately 22 kg. The experiment was run for 28 days with intake and unconsumed feed (feed spilt on the floor and refused feed left in the trough) recorded daily, and pig weights recorded on days 0, 7, 21 and 28.

Statistical analysis

The following linear mixed model, written in symbolic notation, was fitted to the traits.

Trait response ~ mean + gtype + state + size + STWT

gtype:state + gtype:size + state:size

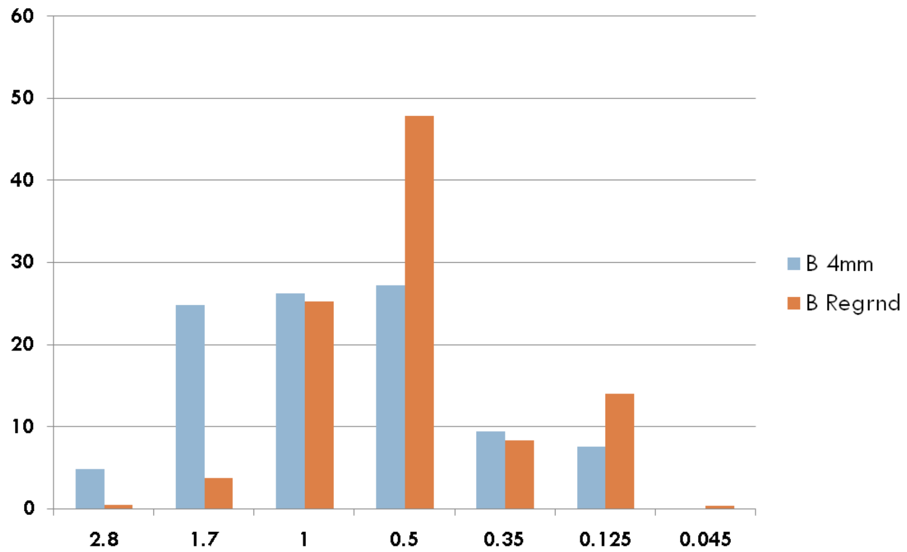
gtype:state:size + **cblock + row + col**

The terms \gtype", \state", and \size" refer to grain type, diet state, and particle size respectively. The term \STWT" refers to pig start weight and is fitted as a covariate. Terms in bold typeface are fitted as random effects to determine if any variation can be attributed to cage blocks, cage rows, or cage columns. For all traits the main effects of, and interactions between grain type, diet state and particle size were tested using incremental F-statistics.

3. Outcomes

Full statistical analyses are given in Appendix 1 and Appendix 2. A summary of the results is shown in Table 1 for the Rivalea weaner pig experiment and in Table 2 for the Wacol grower pig experiment.

Re-grinding to remove the large particles significantly reduced the intake of the sorghum based mash diets with little effect on growth rate for both the weaner and grower pigs. Consequently there was a substantial improvement in feed conversion efficiency. Figure 5 shows that feed conversion ratio (FCR) values were lower (efficiency of feed use higher) for all comparisons of re-grinding with single grinds for all feeds except reground sorghum pellets fed to weaner pigs. Effects were particularly marked for mash feeds with re-grinding resulting in 22% and 10.5% improvement in the efficiency of feed use for sorghum offered, respectively, to weaner and grower pigs. Similarly re-grinding of barley fed as a mash resulted in 15% and 8.3% improvement in efficiency of feed use for weaner and grower pigs, respectively. Re-grinding of either sorghum or barley offered as a mash resulted in a lower FCR than pelleting after a single grind.



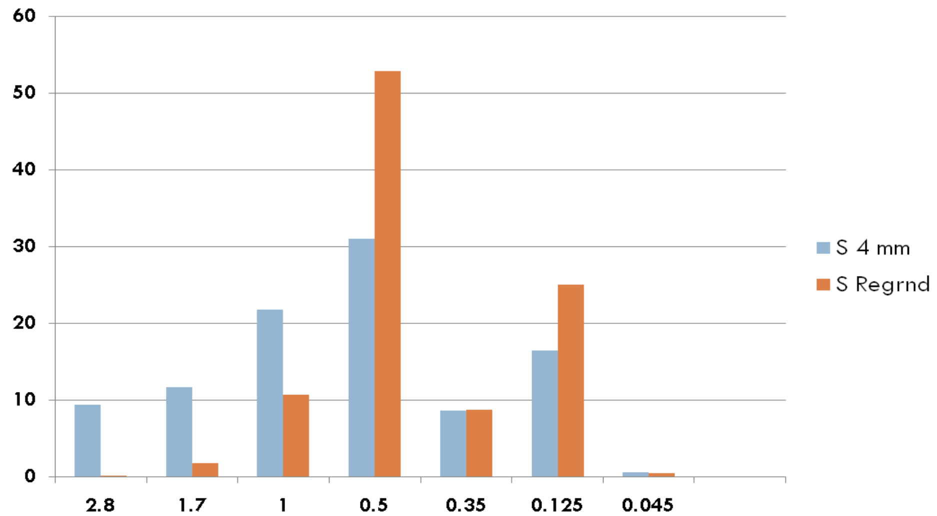


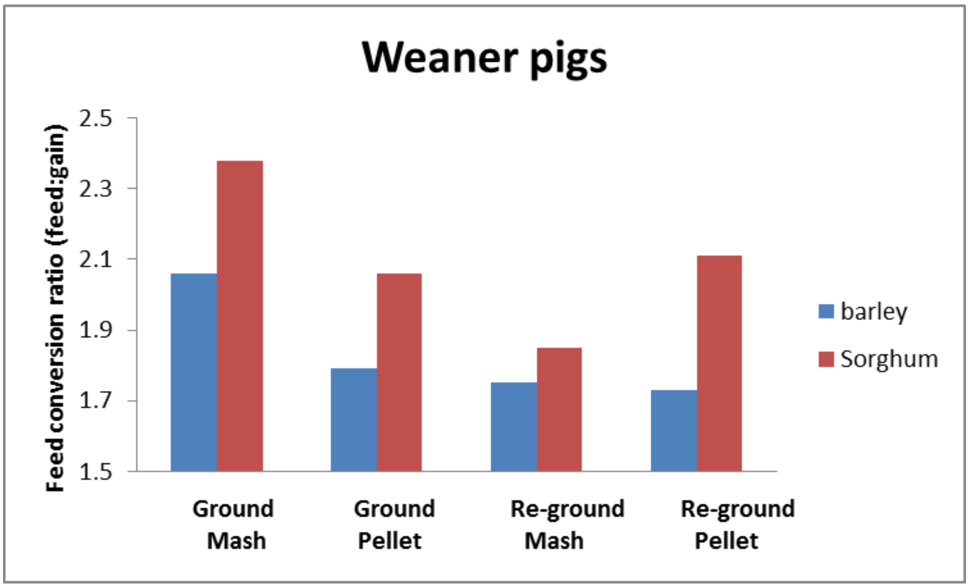
Figure 4 - Particle size distribution after a first hammer milling through a 4 mm screen and after re-grinding those particles captured on 1.8 mm (barley) and 0.9 mm (sorghum) screens.

Table 1 - Rivalea weaner pig experiment. Effects of grain type, particle size and diet form on average daily intake (ADI), rate of gain (ROG) feed conversion ratio (FCR) of pigs from 0-21 days. B = barley; S = sorghum; G = ground once; R = re-ground large fraction; M = mash; P = pellet. * Different letters in a column indicate statistical significance (p<0.05).

Treatment	ADI (±se mean) (kg/day as fed)	ROG(±se mean) (kg/day)	FCR(±se mean) (feed: gain)
BGM	0.47^{a} *± 0.027	0.23^{a} ± 0.013	2.06^{b} ± 0.094
BGP	0.47^{a} ± 0.026	0.27^{b} ± 0.013	1.79^{a} ± 0.089
BRM	0.49^{a} ± 0.027	0.27^{b} ± 0.013	1.75^{a} ± 0.094
BRP	0.45^{a} ± 0.027	0.27^{b} ± 0.013	1.73^{a} ± 0.094
SGM	0.63^{b} ± 0.026	0.27^{b} ± 0.013	2.38^{c} ± 0.091
SGP	0.50^{a} ± 0.027	0.27^{b} ± 0.013	2.06^{b} ± 0.091
SRM	0.50^{a} ± 0.028	0.25^{ab}±0.013	1.85^{a} ± 0.097
SRP	0.46^{a} ± 0.028	0.23^{a} ± 0.013	2.11^{b} ± 0.096

Table 2 - Wacol grower pig experiment. Effects of grain type, particle size and diet form on average daily intake (ADI), rate of gain (ROG) feed conversion ratio (FCR) of pigs from 0-28 days. B = barley; S = sorghum; G = ground once; R = re-ground large fraction; M = mash; P = pellet. * Different letters in a column indicate statistical significance (p<0.05).

Treatment	ADI (±se mean) (kg/day as fed)	ROG(±se mean) (kg/day)	FCR(±se mean) (feed: gain)
BGM	1.621^{a} *± 0.069	0.801^{a} ± 0.030	2.038^{a} ± 0.05
BGP	1.660^{a} ± 0.071	0.841^{a} ± 0.031	1.959^{ab} ± 0.051
BRM	1.597^{a} ± 0.071	0.855^{a} ± 0.032	1.880^{b} ± 0.052
BRP	1.617^{a} ± 0.077	0.852^{a} ± 0.035	1.900^{b} ± 0.055
SGM	1.835^{a} ± 0.074	0.85^{ab} ± 0.033	2.195^{a} ± 0.054
SGP	1.600^{b} ± 0.069	0.795^{b} ± 0.033	2.023^{b} ± 0.050
SRM	1.722 ^{ab}±0.069	0.866^{a}±0.030	1.975^{bc} ± 0.050
SRP	1.592^{b} ± 0.072	0.810^{ab} ± 0.031	1.919^{c} ± 0.052



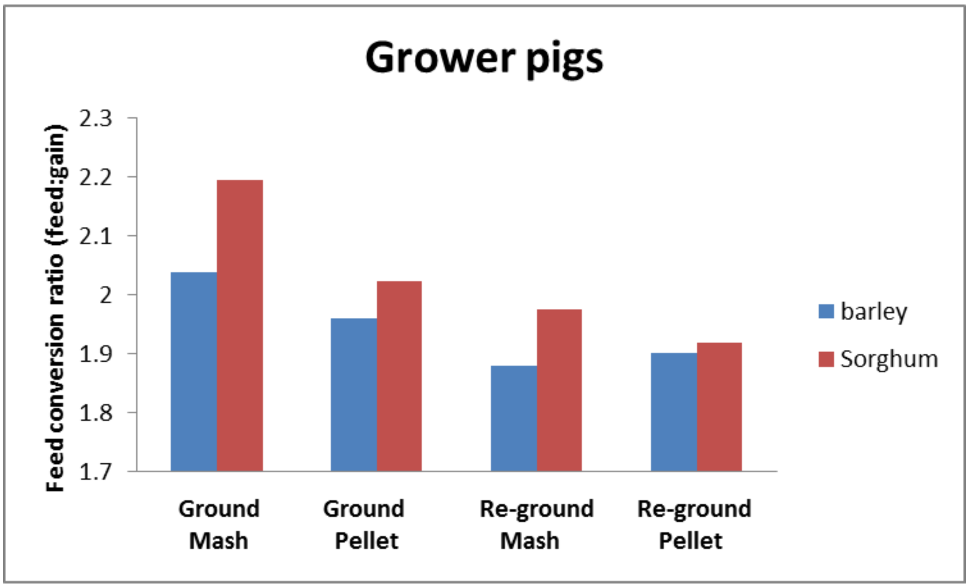


Figure 5 - Effect of re-grinding large particles fed either as mash or conventional pellets on feed conversion ratio for weaner and grower pigs.

Pelleting of conventionally ground grain also resulted in significant improvements in feed conversion efficiency compared with the grain fed as mash for all comparisons except barley based diets offered to grower pigs. Pelleting of once ground sorghum grain diets resulted in 15% and 8% improvements in feed conversion efficiency compared with mash diets, respectively for weaner and grower pigs. Similarly, pelleting improved feed conversion efficiency by 13% compared with mash diets containing barley in weaner pigs.

Pelleting of diets containing re-ground grains did not improve the efficiency of use of either sorghum or barley based diets offered to grower pigs or barley diets offered to weaner pigs. However, pelleting of the re-ground sorghum diet resulted in a significant reduction in the efficiency of feed use by weaner pigs.

4. Conclusion

The experiments show that there are large effects of reducing the size of large particles on the efficiency of feed use by young pigs offered either barley or sorghum based diets. These results are particularly important for pig enterprises offering mash feeds because removal of the large particles resulted in numerically better feed conversion efficiency than traditional milling and pelleting of the diets. Nevertheless, pelleting of diets containing conventionally milled grain resulted in significant improvements in feed conversion efficiency compared with mash diets for all comparisons except barley based diets fed to grower pigs.

Further research is continuing in a new project to identify the best method for milling grains to reduce the maximum size of particles while not increasing the proportion of very fine particles. The research will also determine the likely optimum maximum particle size for each grain type.

5. Appendices

Appendix 1 & Appendix 2 are statistical reports