Effects of grind size in typical grower/finisher diets under commercial conditions

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Executive Summary

A survey of commercial feed mills and home mixers in 2013 revealed a wide range in grain particle sizes. Many samples recorded average particle sizes well above the suggested optimum of 700 micron. This trial explored the effects on animal performance of reducing the average particle size from 1100 to 600 micron, in commercial pelleted diets.

This project involved 3 separate trials using the same protocol and employing 3168 pigs. The diets involved were based on wheat, barley, peas and canola meal and were fed as a grower diet (30 – 60 kg Live weight) 14.2 MJ DE and 0.70 gm Avail. Lysine/MJ DE) and as a Finisher diet (60 – 100 kg live weight, 14.0 MJ DE and 0.60 gm Avail. Lysine/MJ DE).

The treatments applied involved grinding common diets over a disc mill at different settings to create a "fine" product (500 – 600 micron) and a "coarse" product (1000 – 1100 micron). A third treatment was created by blending the fine and coarse versions in a 50:50 mix. The diets were fed *ad libitum* as pellets.

The key finding from the project was that reducing the grind size from 1100 to 600 micron had no effect on ADG but reduced feed intake, resulting in a 2.6% improvement in FCR in the grower phase and 5.6% improvement in the finisher phase.

An interesting artefact of the series of experiments was that one batch of "fine" grower feed was in fact ground to an ultrafine state (440 micron) and this depressed performance.

One of the cautions of finer grinding is the increased risk of gastric lesions but the excellent performance of the pigs in this series of trials and the associated low loss rate (<1.5%) would suggest that this was not a major issue at the particle sizes tested, nor with the combination of grains used.

Many producers in Australia are milling feeds to an average particle size of 1500+ micron which implies there is a huge potential to improve feed efficiency and lower the cost of production by simply adjusting the milling equipment to achieve closer to optimal particle size.

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1. Introduction

The reduction in particle size of grains in the diet of growing/finishing pigs has been shown to improve feed conversion efficiency in both mash and pelleted diets (Wondra 1995, Gidley eta l 2010). However much of the research to date has been conducted with grains other than wheat (e.g. maize, barley and sorghum). There have been limited trials using typical commercial combinations of wheat, barley, peas and canola.

Most grind size studies have also involved comparisons of hammer milled and roller milled grain but with the rise in disc mill use there is interest in responses derived from this milling technique. The various forms of milling equipment can be adjusted to manipulate mean particle size diameter, but they also have a characteristic spread or variance in particle sizes which can affect the animal's response (Wondra, 1995).

In a survey conducted of ground grain samples from commercial feed mills and home mix operations in NSW, Vic, and SA, as part of a project by Dr Peter Sopade of University of Queensland to develop a hand held sieving device to assess particle size, it was revealed that there was a wide range in particle sizes in the grain used. Commercial feed mills using hammer mills to prepare grain for pelleted feeds were achieving reasonable particle size (550 – 800 μm) but with high variance (SD>2.0), while home mixes using mainly roller mills recorded average particle sizes of 1000 – 2000 μm and were visually far too coarse although having tighter variance (SD<2.0). Disc mill operators tended to produce an intermediate but variable range (700 – 1100 μm), with relatively wide variance. This survey confirmed that many feed producers were manufacturing feeds with average particle size well above optimal. This prompted the current study to try to quantitate the consequences of milling feeds at particle sizes well removed from a nominated optimum of 500 – 700 μm based on a range of studies using different grains and different milling techniques.

2. Methodology

A total of 3 experiments were conducted using the same basic protocol. The first was an in-house study which resulted in practical improvements in FCR to finer grinding but the P-values were of the order of 0.08. These results were enough to stimulate an application to be made for CRC funds to repeat the trial to improve the statistical power of the data, and share with industry. Unfortunately due to a misunderstanding 2 of the 8 replicates in this second trial were marketed prior to their final weigh and were not followed to the abattoir. As a consequence it was agreed to repeat the trial again at the facilities expense producing effectively 3 replications of the same experiment – albeit conducted at different times of the year.

A further study was attempted in which the same diets and treatments were employed but the feeds were fed in mash form rather than pellets, to explore grind size independent of pelleting. Unfortunately the mash proved extremely difficult to handle in the facility with the feed sensors in each feeder not recognising the mash and confounding deliveries. This trial was subsequently abandoned.

Experimental design (common to all 3 trials)

1. **Animals**

A total of 1056 female commercial, slaughter pigs were drawn from the weekly production at the breeder source farm and transferred to the research facility. These were drafted into 4 weight categories (Heavy, Medium-1, Medium-2, and Small) and placed in test pens at 22 pigs/pen. A total of 48 pens were employed (12 for each weight category). The configuration of penning at the facility involved pairs of pens sharing a common feeder/valve). So with 24 valves and 3 treatments, there were 8 replicates / treatment (2 within each of the 4 weight categories). The pigs were approximately 9.5 weeks old and 28 kg live weight at delivery and were allowed one week to acclimatize on standard weaner feed before starting the trial.

2. **Diets (treatments)**

The pigs were all fed a common Grower-1 diet from approximately 30 – 60 kg. live weight, followed by a common Finisher-1 diet from 60 kg to slaughter. The composition and theoretical analysis of the base diets is presented in Table 1.

Table 1 - Composition and Analysis of Trial Diets

Composition	Grower 1	Finisher 1
Wheat – 10%	40.07	36.16
Barley – 11%	25.00	35.00
Peas	10.00	10.00
Canola Exp – 34	12.00	12.00
Soybean Meal 46	4.10	-
Meat Meal 55	4.25	2.00
Blood Meal	0.80	0.60
Tallow	2.00	2.00
Salt	0.20	0.20
Limestone	0.95	1.15
Dical-Phos	-	0.30
L-Lysine HCl	0.275	0.255
D,L-Methionine	0.065	0.040
L-Threonine	0.085	0.095
L-Tryptophan	0.005	-
Grower Premix*	0.20	0.20
	100.00	**100.00**
Analysis		
Digestible Energy MJ/kg	14.20	14.0
Protein %	18.40	15.8
Fat %	5.21	5.03
Fibre %	4.53	4.72
Calcium %	0.94	0.91
Av. Phos %	0.43	0.39
Lysine %	1.17	0.99
Av. Lysine %	1.00	0.85
Av. Lys: DE gm/MJ	0.70	0.60
Meth: Lys	0.30	0.30
M + C: Lys	0.63	0.66
Threo: Lys	0.67	0.71
Iso: Lys	0.58	0.58
Trypto: Lys	0.18	0.18
* Containing phytase enzymes @ 500 FTU + NSP enzymes		

The treatments were created by milling the common diet at two different disc mill settings (fine and coarse) and then creating an intermediate treatment by blending these via the feed dispensing system. The disc mills at the source mill operate in a post-grind mode in which all the feed components are mixed (including whole grain and proteinmeals) and then the total batch is passed through the disc mill into the mixer. Following the mixer the feeds are steam conditioned and pelleted in normal commercial manner. The disc mill settings for the 2 base feeds in each phase were.

Fine = DISC MILL SETTING “0” (which is actually as minimum 0.5 mm to avoid the discs touching). This yielded an average particle size of 516 µm measured in the mill QA laboratory.

Coarse = DISC MILL SETTING “1.2” (which is actually 1.7 mm). This yielded an average particle size of 1114 µm.

The treatments were then:

1. Fine
2. Medium (50:50 blend of fine and coarse)
3. Coarse

3. Measurements

ADG, ADFI and FCR were recorded for each phase (by valve – 44 pigs per valve). The pigs were sent to slaughter by weight category (with each treatment equally represented) as they approached 100 kg live weight. Carcass parameters recorded were, carcass weight, dressing %, (on a pen basis) and P2 backfat.

In trial 1 only the heavy category were followed to the abattoir. As there was no apparent influence of treatment on carcass parameters it was decided not to follow the balance of the pigs. In trial 2 all pigs were followed except for the final 2 replicates which were marketed prematurely. In trial 3 all pigs were followed except for the final 2 replicates.

A number of representative samples of the mixed mash feeds collected at the mixer (prior to conditioning) were forwarded to Dr Peter Sopade for independent particle size determination. (Table 2).

Table 2 - Particle size measurements by Dr Peter Sopade (mm)

Trial	Diet	Fine (0.5 mm)			Coarse (1.7 mm)		
		Dgw	**Sgw**	**SD**	**Dgw**	**Sgw**	**SD**
2	Grower	0.44	0.26	1.75	1.23	1.19	2.36
2	Finisher	0.53	0.47	2.23	1.15	0.91	2.06
3	Grower	0.57	0.40	1.92	0.89	0.84	2.32
3	Grower	0.63	0.52	2.12	0.84	0.88	2.51
3	Finisher	0.60	0.42	1.94	1.20	0.99	2.13
Average		**0.554**		**1.99**	**1.062**		**2.28**

Note: Dgw = geometric mean diameter
Sgw = geometric standard deviation of particle diameter
SD = standard deviation of the mean diameter

3. Outcomes

The level of performance recorded across all 3 experiments was quite respectable for commercial facilities, and there was no obvious health compromise at any stage. The targeted particle sizes for the two base treatments were 550 µm for the fine diet and 1100 µ for the coarse. Analysis of the feeds in the first trial (516 and 1114 µm) and subsequent trials (Table 2 averages 554 and 1062 µm) revealed that the intended differential was achieved, though with some variability between samples, particularly in the coarse samples. It must be noted that these are measures of the total feed not just the grain. The non-grain components make up 20 – 25% of the diet and are mostly relatively fine materials. This would explain why the Fine diets recorded an average particle size close to the setting (e.g. 554 compared to 500 µm) while the Coarse diet recorded an average particle size well below the disc mill setting (i.e. 1062 compared to 1700 µm).

Across all 3 experiments the range in particle size had no effect on growth rate. One exception to this was the grower phase in experiment 2. When the feeds were made for this period, the fine feed did not appear visually to be distinguishable from the coarse feed. This was attributed to worn discs on the mill and the feed was subsequently remade after new discs were fitted. This resulted in an ultrafine product which recorded an average particle size of 440 µm.

This finely ground diet resulted in a significant retardation in growth, largely due to a marked drop in feed intake. Apart from this anomaly the general trend across all 3 experiments was that as the particle size was reduced from coarse to fine there was a consistent reduction in feed intake. With no appreciable effect on growth rate this resulted in a corresponding improvement in feed efficiency. The magnitude of these responses varied between growth phases and between experiments and can be summarised as follows. (% Fine relative to Coarse)

Table 3 - Experiment 1 (Conducted March – June 2013)

	Fine	Medium	Coarse	P. Value	SEM
Grower Phase					
ADG gm	853	846	832	0.657	9.62
ADFI kg	1.792	1.829	1.811	0.857	0.026
FCR	2.098	2.161	2.176	0.089	0.015
Finisher Phase					
ADG gm	974	956	976	0.499	7.40
ADFI kg	2.504	2.595	2.574	0.359	0.026
FCR	2.572	2.707	2.638	0.083	0.025
Slaughter Data (Heavy replicates only – approximately 88 pig/treatment)					
Initial L.Wt. Kg.	39.85	38.63	39.40		
Final L. Wt. Kg.	99.50	95.97	95.96		
Av. Carcass Wt. Kg.	74.71	71.97	72.05		
Av. Drressing %	75.10	75.00	75.10	0.989	0.252
Av. P2 Backfat mm	9.75	10.03	9.67	0.458	0.118
ADG gm	962	925	912		
Av. Carcass Gain* kg	44.82^{b}	43.00^{a}	42.49^{a}	0.028	0.407
*** Assumes starting carcass weight = Average start weight x 0.75**					
Mortality	4/352	3/352	1/352		

Table 4 - Experiment 2 (Conducted August – November 2013)

	Fine	Medium	Coarse	P. Value	SEM
Grower Phase					
ADG gm	724^{a}	804^{b}	823^{b}	0.003	13.4
ADFI kg	1.594	1.676	1.765	0.158	0.036
FCR	2.148	2.081	2.141	0.470	0.024

	Fine	Medium	Coarse	P. Value	SEM
Finisher Phase					
ADG gm	926	920	918	0.937	9.16
ADFI kg	2.352	2.411	2.490	0.358	0.039
FCR	2.538	2.620	2.713	0.117	0.035
Slaughter Data (6/8 replicates - approximately 264 pigs/treatment)					
Initial L.Wt. Kg.	33.32	32.62	34.03		
Final L. Wt. Kg.	96.67	97.96	97.53		
Av. Carcass Wt. Kg.	73.45	75.02	73.63		
Av. Dressing %	75.96[a]	76.59[b]	75.49[a]	0.004	0.142
Av. P2 Backfat mm	9.28	9.75	9.51	0.195	0.104
ADG gm	852	879	854		
Av. Carcass Gain* kg	45.64a	47.63b	45.35a	0.005	0.326
* Assumes starting carcass weight = Average start weight x 0.75 and corrected to 70 day growth period					
Mortality	7/336	3/336	4/336		

Table 5 - Experiment 3 (Conducted October - December 2013)

	Fine	Medium	Coarse	P. Value	SEM
Grower Phase					
ADG gm	851	859	862	0.928	11.18
ADFI kg	1.732	1.805	1.839	0.455	0.035
FCR	2.033	2.099	2.130	0.165	0.021
Finisher Phase					
ADG gm	982	976	985	0.867	6.57
ADFI kg	2.375[a]	2.539[ab]	2.601[b]	0.027	0.057
FCR	2.422[a]	2.601[b]	2.629[b]	0.029	0.036
Slaughter Data (6/8 replicates - approximately 252 pigs/treatment)					
Initial L.Wt. Kg.	38.05	38.36	39.60		
Final L. Wt. Kg.	95.97	96.67	98.52		
Av. Carcass Wt. Kg.	72.65	73.44	74.62		
Av. Dressing %	75.76	75.98	75.93	0.803	0.142
Av. P2 Backfat mm	9.27	9.56	9.78	0.333	0.138
ADG gm	934	932	950		
Av. Carcass Gain* kg	44.83	45.01	45.65	0.623	0.353
* Assumes starting carcass weight = Average start weight x 0.75 and corrected to 63 day growth period					
Mortality	7/336	2/336	12/336		

Table 6 - Combined Data – All 3 Experiments

	Fine	Medium	Coarse	P. Value	SEM
Grower Phase					
ADG gm	810	836	839	0.228	7.58
ADFI kg	1.706	1.770	1.805	0.116	0.020
FCR	2.093	2.114	2.149	0.154	0.012
Finisher Phase					
ADG gm	961	951	960	0.709	5.38
ADFI kg	2.410a	2.515b	2.555b	0.011	0.021
FCR	2.511a	2.642b	2.660b	0.001	0.019
Slaughter Data The data sets across the 3 experiments are unbalanced and could not be consolidated.					
Mortality	18/1024	10/1024	17/1024		

Table 7 - Response to fine grinding - % Difference between the fine diet and the coarse diet

Experiment	Phase	Feed Intake	FCR
1	Grower	- 1.0	- 3.6
	Finisher	- 2.7	- 2.5
2	Grower*	- 9.7	+ 0.3
	Finisher	- 5.5	- 6.5
3	Grower	- 5.8	- 4.6
	Finisher	- 9.7	- 7.9
Combined	**Grower**	**- 5.5**	**- 2.6**
	Finisher	**- 5.7**	**- 5.6**
* Affected by ultrafine grinding of the "fine" diet.			

The medium particle size treatment (50:50 fine/coarse) was intermediate in its responses, but closer to the coarse treatment. There was no consistent effect of grind size on carcass gain, dressing % or P2 backfat. Mortality across all experiments was relatively low (<2.0%) and there was no consistent association with particle size.

4. Application of Research

This series of trials has confirmed that particle size reduction from around 1100 µm to 600 µm results in improved FCR with little effect on ADG. This is consistent with many other trials (Wondra, 1995, Ohh *et al*., 1983, Healy *et al.*, 1994) as is the finding that extremely fine milling (less than 400 µm) can result in the deterioration of both ADG and FCR.

The improvement in FCR appeared more apparent in the finisher phase. This is in agreement with Goodband (1996) who states that the potential for fine grinding to improve FCR is greatest in finisher pigs. It may also reflect the greater barley inclusion in the finisher diet, as barley tends to respond more to fine grinding than wheat (Goodband and Hines, 1996). In the study by these authors the FCR improved by 6.8% when the average particle size of the barley was reduced from 1278 to 663 µm – a similar magnitude to that in this current study.

One of the cautions of fine grinding is the increased risk of gastric lesions (keratinisation/ ulcers). However, the threshold for this may occur below the nominated optimal particle size of 600 – 700 µm. Mavromichalis *et al*., (2000) compared a grind size range of 1300, 600 and 400 µ in wheat based diets for finisher pigs and found no evidence of lesions at 1300 µm and a minor incidence of stomach lesions at 600 µm but significant evidence of damage at 400 µm. Although stomach lesions were not monitored in the current study, the improved performance at the finer particle size and the low overall mortality would suggest there was little issue with gastric damage associated with finer grinding at this level (and with this combination of grains). The grind size measurements did vary between different batches of feed despite a common formula and the same settings on the disc mill. This highlights the need for constant surveillance as a QA function to ensure that the intended grind size target is being met. The variability may be due to wear on the discs or with the way in which the materials present for grinding e.g. either as sequential parcels of different materials or as a homogenous mix of all materials.

The responses to grind size tend to relate directly to the grain involved rather than the complementary protein meals and additives in the feed. Lawrence *et al.*, (2003) conducted a trial with nursery pigs in which they fed corn/soya diets with a common corn grind size but variable soyabean meal grind sizes from 1226 to 444 µm, and found the variation in soyabean meal particle size had no effect on ADG, ADFI or FCR. The explanation for this probably lies in the fact that these non-ground materials have been processed in some way prior to entering into the formula (e.g. prior grinding, heating, solvent extraction, etc.) and as such are reasonably accessible to digestive enzymes even if they record average particle sizes higher than the nominated optimum of 600 – 700 µm.

It is disappointing that we had to abandon the mash phase of this series of trials as this would have been valuable to assess the response to grind size for home mixers independent of that for commercial pelleted feed users. We will revisit this once we overcome the physical logistic issues.

In the CRC trials by Gidley *et al.,* (2010) pelleting a mash barley diet resulted in a 3.9% improvement in FCR. However simply sieving out the large particles (>1700 µm) regrinding this fraction and returning them to the mix resulted in a 7.9% improvement in FCR. Pelleting this reground mix provided no further benefits. This implies that if the grinding can achieve the right particle size profile in the first instance there may be no further benefit in pelleting feed and this cost could be saved.

The improvement in FCR to fine grinding of the order of 5% witnessed in this current series of trials is of considerable commercial merit. In the grower/finisher phase from 30 kg live weight to slaughter at 100 kg, pigs will consume around 170 kg of feed. A 5% reduction in FCR equates to 8.5 kg of feed or a saving of approximately $3.80/pig (5 c/kg off the cost of production). This advantage could also be expressed as a $22.50/tonne reduction in the cost of feed. Wondra *et al.,* (1992) demonstrated the increased power cost and compromise to production rate as particle size is reduced. However, the cost differential between 1000 and 600 µm was modest and only began to accelerate below 600 µm. The additional milling costs in the current exercise would represent only a very minor offset to the $22.50/tonne advantage identified.

The floury nature of wheat endosperm and the risks of handling difficulties, gastric ulcers and dust generation, when finely ground as well as the relatively free access of enzymes to the starch granules once the seed coat is ruptured, probably indicates that the optimal particle size for wheat in pig diets may be higher than that for the more vitreous grains (corn), fibrous grains (barley) or where the starch is encapsulated in a protein matrix (sorghum). Wondra *et al.,* (1992) nominated the optimum particle size for corn, barley and sorghum to be 700 µm but for wheat suggested 800 – 900 µm may be more appropriate. They further suggested that roller mills are the preferred milling method for wheat, producing a more uniform particle size range and fewer fines

5. Conclusion

The benefits of milling feed to an average particle size of 600 – 700 µm have been demonstrated. The fact that many producers in Australia are milling feeds with average particle sizes of 1500+ µm implies that there is a huge potential to improve feed efficiency and lower the cost of production, simply by adjusting the milling equipment close to optimal particle size. This is not just a once – off procedure but rather an ongoing quality assurance activity to ensure the correct grind size is maintained.

6. Recommendations

The current series of trials has not defined the optimum particle size for wheat/barely/pea diets, but has indicated the optimum is closer to 600 μm than it is to 1100 μm

7. References

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