Influence of hammer mill screen size and grain source (wheat or sorghum) on the growth performance of male grower pigs

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Executive Summary

A total of 864 male growers (Large White x Landrace, PrimeGro™ genetics) were selected at 10 weeks of age and housed in group pens of 18 pigs per pen. Pigs were selected over a six week period, 8 pens per week with a start weight of 24.42 ± 0.11 kg (mean ± SE). Within replicate, pens were randomly assigned to a 2 x 2 factorial experiment, with the respective factors being hammer mill screen size (2 mm and 3 mm) and the predominate grain source in the diet (wheat or sorghum).

Reducing the hammer mill screen from 3mm down to 2mm reduced average particle size in all three grains (wheat: 639 and 552 µm; sorghum: 654 and 602 µm; barley: 676 and 639 µm respectively for the 3mm and 2mm screens). Durability of the pellet was superior when sorghum was excluded from the diet, regardless of hammer mill screen size. Pellet quality of sorghum based diets was improved by utilising the 3 mm screen size, thereby reducing the percentage of fines in the diet. Over the entire experimental period there was a tendency for screen size to influence feed intake (1.41 and 1.45 kg/d respectively for the 2 and 3 mm screen size, P=0.078), although there were no impacts on daily gain or feed efficiency. Sorghum inclusion did not significantly influence feed intake, but did reduce growth performance (738.4 and 707.3 g/d respectively for the wheat and sorghum based diets), resulting in a poorer feed efficiency during this time (FCR 1.95 and 2.02 respectively, P=0.029). The effect of sorghum inclusion on feed efficiency was particularly evident during the initial 21 day feeding period when the grain was passed through the 2 mm screen due to the poorer pellet quality (increased fines and reduced durability), and therefore increased feed wastage. In contrast, feed efficiency in the wheat based diets tended to improve when the screen size was reduced to 2 mm (FCR 1.89 and 2.00 respectively for the 2 mm and 3 mm screen size, P=0.062, sed 0.049). Live weight at the end of the experimental period was not influenced by screen size (P=0.598), but tended to be lower when sorghum was included in the diet at 60 % (60.6 and 59.1 kg respectively for the wheat and sorghum diets, P=0.059). Mortality data indicates a trend for increased mortalities in the pigs offered the sorghum diets (x^2 = 0.345, P=0.063), although this result is associated with a couple of pens with high numbers of *Actinobacillus pleuropneumoniae* (APP) related deaths. The results from this investigation suggest that the 3 mm screen size should be used if sorghum is to be included in grower pig diets through a hammer mill system in order to maximise pellet quality and reduce feed wastage. In contrast, the smaller screen size of 2 mm will maximise feed efficiency when wheat is the predominant grain source.

Table of Contents

Executive Summary i

1. Introduction 2

2. Methodology 3

3. Outcomes 4

4. Application of Research 10

5. Conclusion 12

6. Recommendations 12

7. References 13

1. Introduction

Traditionally, wheat and barley have been widely used as the primary grain sources for pig feed in southern Australia. Increasing costs of these grains for feed manufacturing due to reduced availability has led nutritionists to investigate the use of alternative grains such as sorghum. In comparison to wheat, processed sorghum is similar in digestible energy value for pigs, but can be lower in crude protein concentration (SCA 1987). Amino acid digestibility of sorghum is lower than that of wheat due to the presence of anti-nutritional factors including tannins and kafirins. Tannins are able to bind, coagulate and precipitate proteins, while kafirins (the main protein storage bodies in sorghum) reduce protein digestibility due to their high concentration of cysteine and therefore disulfide-bound complexes which are poorly degraded by the pig. In sorghum, the digestibility of lysine and threonine is particularly low compared to the other amino acids (0.74 and 0.75 respectively (van Barneveld 1999)) and needs to be taken into consideration in feed formulation. The potential nutritive value of new, tannin free sorghum varieties is reported to be similar to corn, with a recent study in the United States reporting similar ileal and total tract digestibility between the two grains in terms of dry matter, energy, phosphorus, calcium and nitrogen (Nyannor *et al.* 2007).

Processing of grain prior to feed manufacturing is common practice to reduce particle size, thereby increasing the surface area of the grain susceptible to the pig's digestive enzymes. The result is generally an improvement in nutrient digestibility and hence enhanced growth performance of the animal. The optimum grind size differs with the type of grain and age of the pig. For example the optimum mean particle size of wheat for weaner pigs has been reported to be 600µm, while for finishers the optimum particle size for maximising feed efficiency was 400 µm (Mavromichalis *et al.* 2000). Processing of sorghum grain is essential prior to feed manufacturing to maximise energy available for use by the pig. The starch granules in sorghum are imbedded in a protein matrix that forms a continuous layer around the edge of the endosperm and the individual starch granules. This protein matrix must be broken down in order to expose the starch granules to digestion by the carbohydrate enzyme amylase. Hammer milling is commonly used in commercial feed mills to reduce the particle size of the grain. The hammer mill utilises metal arms that grind the grain by pushing it through a metal screen, with particle size altered through the use of different screen sizes. Current commercial screen sizes can vary depending on the range of animal feed being produced. At present, the QAF feed mill uses a 3.25 mm screen, while other feed mills may use screen sizes down to 2 mm.

Given the increased utilisation of sorghum in pig diets, it is important to clarify whether differences in hammer mill screen size will impact on production performance of growing pigs when either wheat or sorghum are utilised as the predominate grain source. Therefore the following study tested the hypothesis that growth performance of group housed growing pigs would be similar when fed either sorghum or wheat based diets, and would not be influenced by hammer mill screen size.

2. Methodology

Animals and treatments

A total of 864 male growers (Large White x Landrace, PrimeGro™ genetics) were selected at 10 weeks of age and housed in group pens of 18 pigs per pen (0.54m^2/pig). Pigs were selected over a six week period, 8 pens per week with a mean start weight of 24.42 ± 0.11 kg (mean ± SE). Within replicate, pens were randomly assigned to a 2 x 2 factorial experiment, with the respective factors being hammer mill screen size (2 mm and 3 mm) and the predominate grain source (wheat or sorghum). The ingredient compositions of the wheat and sorghum diets are displayed in Table 1.

Husbandry and management

Pigs were housed in commercial grower pens within the QAF Research and Innovation unit. All animals had *ad libitum* access to feed for the entire experimental period. Pen weights were recorded at the start (day 0), day 21 and day 49 of the experimental period. Pen feed intakes were also recorded over these time periods as measured by feed disappearance and feed conversion efficiency subsequently calculated. All deaths and removals were recorded and taken into account when calculating feed intake and feed efficiency by the adjustment of the number of days that pigs were on trial.

Feed analyses

The particle size distribution of wheat, sorghum and barley after hammer mill processing was assessed by passing a representative sample through a series of sieves (sizes ranging from 150µm to 2mm). Pellet quality was assessed by measuring pellet durability and the percentage of fines in the finished sample. Pellet durability was measured using a Holmen Pellet Durability Tester (Holmen, UK), while the percentage of fines was determined by passing a representative sample through a 2 mm sieve and calculating the percentage of the total sample that passed through the sieve.

Statistical analyses

Differences in growth performance due to the effects of hammer mill screen size and grain source were analysed using an analysis of variance (ANOVA) for a completely randomized design. The model included the main effects of screen size and grain source, with replicate included as the random effect to account for the blocking factor. The experimental unit for all analyses was the pen of animals. All analyses were performed using Genstat 10th Edition (Payne *et al.* 2005).

Table 1. Ingredient composition and nutrient profile of the grower diets, % of diet (as fed basis)

Ingredient, %	Wheat	Sorghum
Wheat	64.95	6.95
Sorghum	0	60
Barley	10.4	8.36
Canola Meal	15.0	15.0
Meat Meal	4.43	5.13
Blood Meal	1.0	1.06
Water	1.0	1.0
Phytase Enzyme	0.015	0.015
Tallow	1.23	0.5
Salt	0.2	0.2
Limestone	1.3	1.2
Lysine HCL	0.276	0.35
MHA	0.0	0.014
Threonine	0.028	0.047
Copper	0.1	0.1
Rumensin	0.1	0.1
Vitamin and mineral grower premix	0.0667	0.0667
Estimated nutrient composition, %*		
Crude protein	18.95	17.2
Crude fat	3.25	3.63
Crude fibre	4.29	4.25
DE, MJ/kg	13.7	13.7
Total Lysine	1.00	0.99
Available lysine	0.85	0.85
Available lysine: DE	0.62	0.62

*Estimated from composition of ingredients (SCA 1987)

3. Outcomes

Reducing the hammer mill screen size from 3 mm to 2 mm reduced average particle size in all three grains (wheat: 639 and 552 µm; sorghum: 654 and 602 µm; barley: 676 and 639 µm respectively for the 3mm and 2mm screens). The influence of screen size on particle size distribution from the three grain sources is displayed in Figure 1. Comparing the particle size distribution of wheat and sorghum, the hammer milling of wheat resulted in slightly more small particles (particles below 710 µm) regardless of hammer mill screen size. In comparison, the hammer milling of barely resulted in a greater proportion of larger particles. The influence of grain source and screen size on finished pellet quality is displayed in Figures 2 and 3 as measures of pellet durability and the presence of fine particles. Durability of the pellet was superior when sorghum was excluded from the diet, regardless of screen size

(Figure 2), while the percentage of fines was reduced in sorghum based diets by utilising the 3 mm screen (Figure 3).

Growth performance, feed intake and feed efficiency during the experimental period are displayed in Table 2. During the initial 21 day feeding period there were no differences in feed intake, daily gain or feed efficiency due to hammer mill screen size. Feed efficiency was improved during this period when sorghum was excluded from the diet (FCR 1.78 and 1.86 respectively for the wheat and sorghum diets, P=0.049, sed 0.038). Interestingly, the FCR effect in the 0-21 day period was most apparent when the smaller screen size of 2 mm was used (interaction P=0.029). During the subsequent period from 21-49 days, pigs offered diets utilising the 3mm screen size (independent of sorghum inclusion) consumed more feed (1.59 and 1.66 kg/d respectively for the 2 and 3 mm screen size, P=0.031, sed 0.035), although there was no impact on daily gain or feed efficiency (Table 2). Feed intake was not influenced by sorghum inclusion during this period, while growth rates tended to be greater (4.8%) when sorghum was excluded from the diet (796.0 and 758.0 g/d respectively for the wheat and sorghum diets, P=0.080, sed 21.30).

Over the entire experimental period (49 days) there was a tendency for hammer mill screen size to influence feed intake independent of sorghum inclusion (1.41 and 1.45 kg/d respectively for the 2 and 3 mm screen size, P=0.078, sed 0.026), while there were no impacts on daily gain or feed efficiency. Sorghum inclusion did not significantly influence feed intake, but did reduce growth performance by approximately 4 % (738.4 and 707.3 g/d respectively for the wheat and sorghum diets, P=0.040, sed 14.61), resulting in a poorer feed efficiency during this time (FCR 1.95 and 2.02 respectively, P=0.029, sed 0.035). Similarly, live weight at the end of the experimental period was not influenced by screen size (P=0.598), but tended to be lower when sorghum was included in the diet at 60 % (60.6 and 59.1 kg respectively for the wheat and sorghum diets, P=0.059, sed 0.789).

The influence of hammer mill screen size and sorghum inclusion on mortality is displayed in Table 3. Chi-squared analyses suggests a trend for increased mortalities in the pigs offered the sorghum diets (x^2 = 0.345, P=0.063). There was no main effect of hammer mill screen size on mortality (x^2 = 0.55, P=0.46).

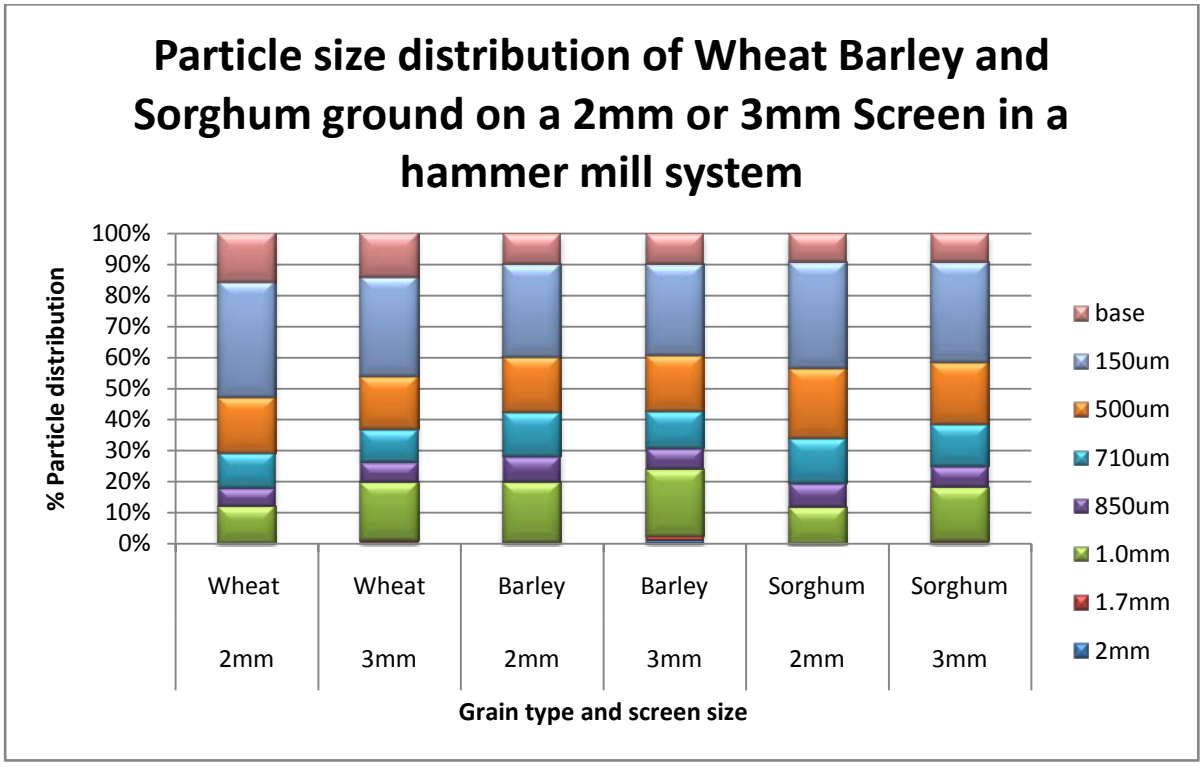

Figure 1. Particle Size distribution of wheat, barley and sorghum ground through a two and three millimetre screen in a hammer mill system.

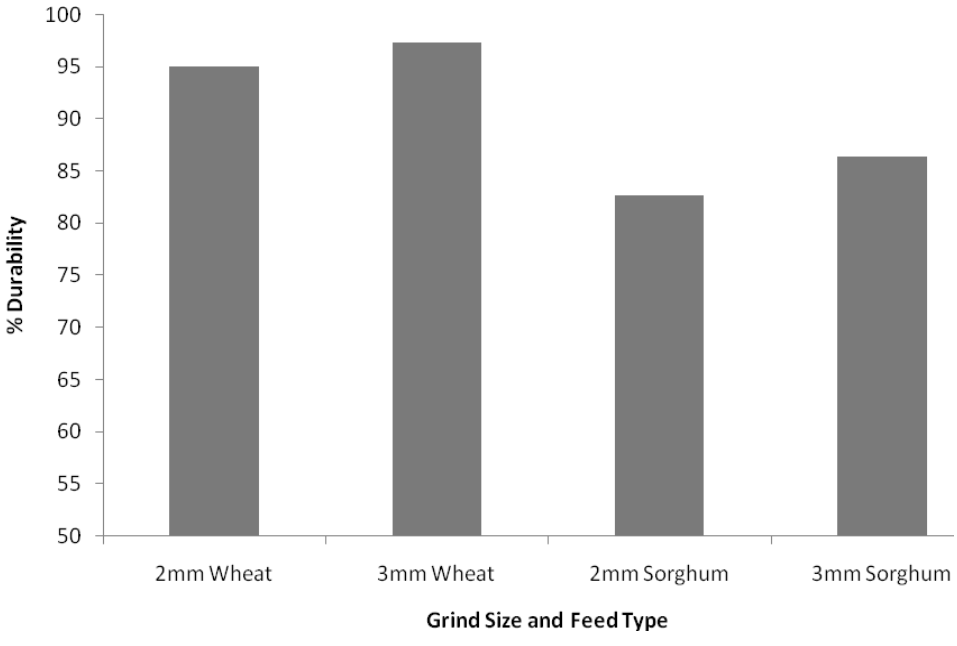

Figure 2. Influence of screen size and sorghum inclusion on feed durability

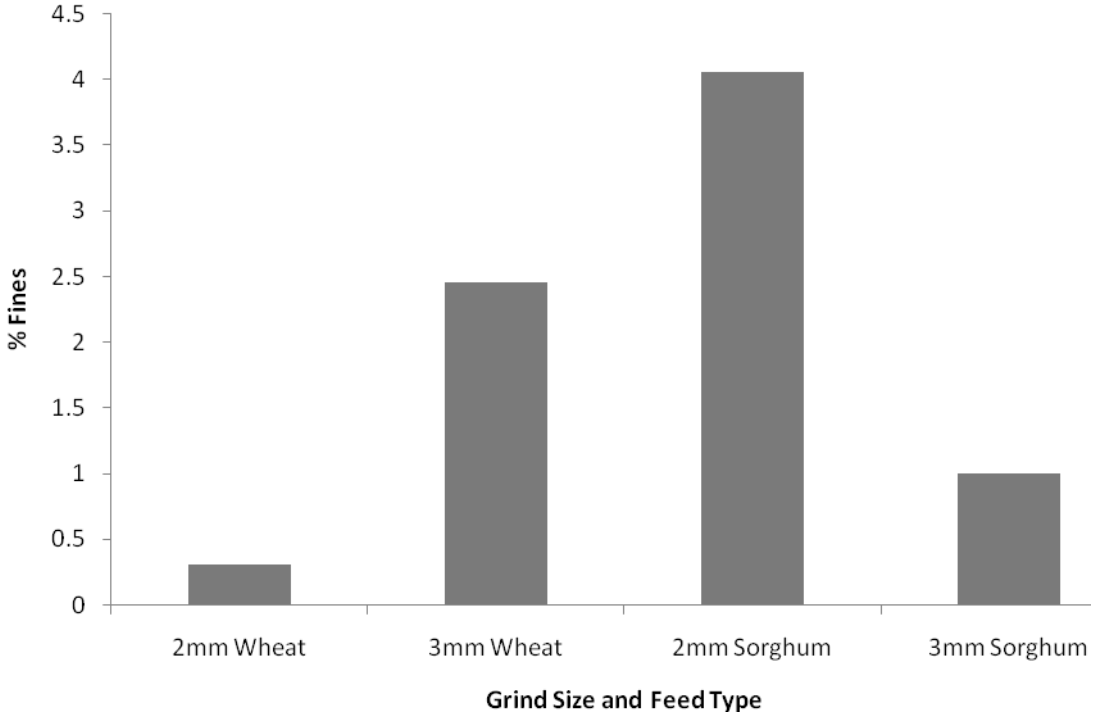

Figure 3. Influence of screen size and sorghum inclusion on the percentage of fines in grower feed

Table 2. Influence of hammer mill screen size and grain source (wheat or sorghum) on the growth performance of male grower pigs

	2 mm screen size		3 mm screen size		SED	Significance		
	Wheat	Sorghum	Wheat	Sorghum	Screen size x Grain	Screen Size	Grain	Screen Size x Grain
Average daily gain (g/d)								
0-21 days	663.1	624.4	660.5	655.9	22.26	0.37	0.18	0.29
21-49 days	806.0	744.0	786.0	771.0	30.10	0.86	0.080	0.28
0-49 days	744.6	692.7	732.2	721.9	20.66	0.57	0.040	0.16
Average daily intake (kg/d)								
0-21 days	1.16	1.19	1.18	1.18	0.035	0.77	0.61	0.47
21-49 days	1.60	1.57	1.67	1.65	0.049	0.031	0.57	0.96
0-49 days	1.41	1.41	1.46	1.45	0.036	0.078	0.84	0.79
Feed conversion ratio								
0-21 days	1.75	1.91	1.81	1.80	0.055	0.59	0.049	0.029
21-49 days	1.98	2.13	2.13	2.17	0.081	0.099	0.12	0.36
0-49 days	1.89	2.04	2.00	2.01	0.049	0.20	0.029	0.062

Table 3. Influence of hammer mill screen size and sorghum inclusion on grower pig mortality

		Deaths, removals Day 0-21			Deaths, removals day 21-49					Total deaths and removals
Screen Size	Grain	Sudden death	APP	Lame	Sudden death	APP	Lame	Unthrifty	Unaccounted for	
3 mm	Wheat		1	1	2		1	1		6
3 mm	Sorghum	2		1	4	2	1	1		11
2 mm	Wheat				2		1		1	4
2 mm	Sorghum	2			3	2	1		1	9

4. Application of Research

Hammer mill screen size significantly influenced grower pig growth performance when sorghum was included as the primary grain source. Reducing screen size from 3 mm to 2 mm was associated with poorer feed efficiency, an increase in pellet fines and a decrease in pellet durability. In combination, these results suggest that the 3 mm hammer mill screen should be utilised when growing pig diets are predominately sorghum based. The overall reduction in growth performance with the sorghum diets suggests that an inclusion rate of 60 % sorghum may have been too high for grower pigs and that further research is warranted to determine maximum sorghum inclusion concentrations for group housed growers. A recent dose response study in this facility indicated that sorghum could be included in diets for individually housed growers at up to 60 % without any negative impact on rate of gain. The study did however report a decline in feed efficiency with the 60 % sorghum diet due to feed wastage (presumably due to poorer pellet quality with the high sorghum diet). This may explain the reduction in growth performance and poorer feed efficiency in the current study while feed intakes (as measured by feed disappearance) remained similar between the wheat and sorghum based diets. Since this experiment was undertaken, pellet quality of sorghum based diets has continued to improve with minor changes to the feed manufacturing processes. If pellet quality of sorghum based diets can be improved to match the quality of wheat based diets, then similar growth performance may be anticipated.

To the best of our knowledge, a trend for increased grower mortality when pigs are offered sorghum based diets has not been previously reported. Given the prevalence of *Actinobacillus pleuropneumoniae* (APP) in the herd at the time of this investigation, it is likely that some of the deaths classified as 'sudden deaths' were also due to APP infection. Further analyses of the data indicated a couple of 'problem' pens, such that five pigs died from one pen offered the sorghum diets, while another pen had three deaths. The other deaths were spread throughout the remaining sorghum pens, with one or two deaths in some pens. There were a similar number of pens from both treatment groups that did not record a death or removal (14 pens offered the sorghum diets and 16 pens offered the wheat diets that did not record a death or removal). This suggests that the trend for an increased mortality in the pigs offered the sorghum based diets may be the result of a couple of pens displaying higher than normal death rates. This is further supported by a recent study in this facility in which sorghum was included at rates of up to 60 % in diets for individually housed growers without any negative impact on mortality. It is however interesting to note that the piggeries in northern Australia that have used sorghum based diets more commonly in the past do not have the prevalence of APP that is reported in Southern Australia. Given this, a nutrient and disease interaction cannot be ruled out by the results in this present investigation, and as such further research may be warranted under commercial conditions.

Reducing mean particle size of grains for animal consumption improves nutrient digestibility and hence growth performance and feed efficiency. The use of the smaller screen size in this investigation reduced mean particle size of all three grains assessed, with the magnitude of

this reduction greater in wheat, followed by barely and then sorghum. Reducing hammer mill screen size for the wheat based diets in this investigation resulted in an improvement in feed efficiency of approximately 5 %. This result is however not consistent across grains, with daily gain declining when the screen size was reduced from 3 mm to 2 mm in sorghum based diets. Hansen *et al.* (2007) reported similar feed intakes and daily gain between growing pigs fed pelleted diets in which the grain component (wheat, barley and sorghum) had been passed through either a 2.0 mm screen or a 3.5 mm screen. Feed efficiency did however improve by approximately 3 % with the reducing screen size, although this was not significant. These results in combination with the growth performance and feed quality measures in this present investigation suggest that the use of smaller hammer mill screen sizes may improve growth performance and feed efficiency of growing pigs when the diets are predominately wheat based. In contrast, the larger screen size should still be utilised for sorghum based diets to maximise pellet quality. It has been suggested that particle size uniformity may be more important than mean particle size. Investigations by Wondra *et al.* (1995) observed consistently greater nutrient digestibility when the corn based diets had more uniform particle sizes. This may indicate that further research is required to investigate the impact of particle size uniformity across a range of grain sources on pig growth performance and nutrient digestibility. Depending on the outcomes of this investigation, strategies to improve particle size uniformity in the mill may then be worthy of further investigation.

Optimising animal growth performance and feed efficiency is not the only consideration when determining the most economic hammer mill screen size and grain source to include in grower and finisher diets. The inclusion of particular grains can have a marked impact on feed manufacturing throughput rates, energy efficiency and pellet durability depending on the inclusion concentrations. Reducing particle size of the grain will also reduce feed production rates and increase energy required to produce the diet (Healy *et al.* 1994). As such, determining the optimum screen size for processing of grower and finisher diets also needs to take into consideration the costs associated with feed processing given that grower and finisher diets account for approximately 60 % of the overall feed used on farm. The impact of grain source and screen size on overall cost efficiency is outside the scope of this investigation, but is the focus of another CRC project (Project number 1B-107, Quality assessment of feed grains). This project will also clarify the impact of other products such as enzymes on processing rates, energy efficiency and overall production costs.

5. Conclusion

The results from this investigation suggest that the 3 mm screen size should be used to maximise pellet quality if sorghum is to be included in grower pig diets processed through a hammer mill system. In wheat based diets feed efficiency may be maximised by utilising a 2 mm screen. The outcomes from this investigation suggest that further research is required in a number of areas to improve the utilisation of sorghum for maximum growth performance of growing pigs.

6. Recommendations

Areas for further investigation include:

Dose response studies to determine the maximum sorghum inclusion rates for growing pigs under commercial, group housed conditions

Investigations into possible interactions between nutrition and disease, including the impact of sorghum on APP prevalence

The influence of particle size uniformity and maximum particle size of different grain sources on grower/ finisher growth performance and feed efficiency

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