Australian Government
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AUSTRALIAN Pork™

Nutritional Strategies to Minimise the Influence of Bedding Material Consumption on Growth Efficiency

Final Report
APL Project 2005/2012

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Non-Technical Summary

Project Objectives

- Definition of the upper level of bedding material intake by pigs housed in commercial deep-litter systems accounting for an increase in the level of bedding material fouling over time.
- Definition of the increase in ad libitum intake in formulated diet consumption when pigs consume a proportion of their diet as bedding material.
- Quantification of the effect of bedding material intake on the digestibility of other dietary nutrients.
- Development of nutritional strategies to compensate for the consequences of bedding material consumption by pigs housed in deep litter systems.
- Validation of remedial diet formulation and feeding strategies in commercial deep litter production systems and recommendations to commercial producers.

Project Outcomes

This project has been very successful at achieving the stated objectives and providing the Australian pork industry with solutions for the optimal nutrition of growing pigs housed in deep litter systems. The project outcomes include:

1. The amount of bedding material consumed as a percentage of the total diet consumed appears to be consistent across time and weight, with approximately 7% of the total diet of pigs housed on cereal straw being bedding material. This percentage does not change as the area of spoiled bedding material increases. This finding means that formulated diet adjustments can be made to compensate for this bedding material intake and these adjustments will be applicable regardless of pig weight and degree of bedding material spoilage.
2. This research has demonstrated that when pigs have access to bedding material there is no significant change in their intake of formulated feeds. It has also demonstrated that if there is an interruption in provision of formulated feed (say through a feed system blockage or delayed feed truck in a commercial system) that pigs do not increase their consumption of bedding material to compensate, however, this may be dependent on growth phase and bedding material type (in this experiment, growing pigs housed on barley straw did increase their intake of straw when provision of formulated feed was interrupted, but this difference diminished in the finisher phase). It would be reasonable to include that feed interruptions during the grower phase (when energy is the primary driver of intake) can induce an increase in consumption of palatable bedding material, but otherwise the effects are minimal.
3. Results from this experiment demonstrate that consumption of as little as 5% bedding material is sufficient to significantly depress the ileal and faecal digestibility of energy, protein, amino acids and minerals and to reduce the digestible lysine to digestible energy content of a grower diet by as much as 10 to 15 %. This will influence the overall efficiency of production in deep litter systems and will need to be accommodated for when formulating diets. Higher inclusion levels were shown to result in a significantly greater depression of some nutrients, however, based on outcomes from Experiment 1, it would be pertinent to formulate to a digestibility depression consistent with a 7% inclusion of bedding material. Unfortunately, the observation that rice hulls had different effects to barley straw on nutrient digestion (which is by no means surprising) means nutrient digestibility adjustments will need to be bedding material specific.
4. The results from this research suggest that a remedial nutrition strategy is worthwhile for pigs housed on deep litter systems, demonstrate that approximately 7% of the intake is bedding material over the entire grower/finisher phase regardless of level of bedding material fouling, shows that pigs generally do not compensate for bedding material intake through higher

formulated feed intake, and that at 5% bedding material intake, there is a significant depression in the digestibility of energy, amino acids and minerals. Taking all of this into account, the remedial strategy becomes very simple – formulate diets with a 5% up-specification of energy, amino acids and minerals, or incorporate appropriate enzymes to facilitate this.

5. This is the only inconclusive aspect of this project, but in no way diminishes the value of the research. It appears that a lack of experimental power has prevented the demonstration of a significant benefit of the remedial formulation, but the numerical FCR data is in line with expectations – the down specified diet had the poorest FCR with the remedial diet the best. The magnitude of the difference is worthy of note and as a consequence, it would be irresponsible to suggest that remedial diets do not make a difference to the performance of pigs housed in deep litter systems.

Implications and Recommendations

Completion of this project has provided some very definitive and unique data on the consumption of bedding material by growing pigs housed in deep litter systems. The results are conclusive and provide a very simple and practical strategy for the remedial formulation of diets to compensate for bedding material intake. The structure and comprehensive nature of the project means that little additional research is required for these results to have a useful impact on the efficiency of Australian pork production. What remains is to effectively communicate these results through scientific publications, specific APL publications, industry seminars and the popular pork industry press.

Acknowledgements

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This project was made possible with the technical assistance of Mr Robert Hewitt (CHM Alliance Pty Ltd), Mr Steve Peucker (formerly of the Queensland DPI&F), Dr Hugh Dove (CSIRO), Ms Meegan Vandepeer (formerly of Barneveld Nutrition Pty Ltd) and Dr Jae Kim (DAFWA). This project was approved in part by the Queensland DPI&F Animal Ethics Committee, SA2006/05/110 and DAFWA Animal Ethics Committee, 5-08-34 & 5-10-33.

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Project Background

Consumption of deep litter material by pigs housed in deep-litter (DL) housing systems is thought to reduce the efficiency of nutrient utilisation and subsequent production efficiency, but the extent of this is yet to be quantified. It is thought that reduced efficiency of nutrient utilisation in DL housing systems resulting from the consumption of deep litter material in addition to formulated feeds could be a consequence of:

- Consumed deep litter material diluting total digestible energy intake resulting in slower than expected growth;
- Consumed deep litter material reducing the efficiency of nutrient digestion in the small intestine;
- Diluted digestible energy intake resulting in increased feed consumption up to the point of gut fill or energy satiety;
- Changes in the digestible amino acid:digestible energy ratio of the pig's diet (which will depend on the proportion of deep litter material consumed relative to formulated feed) resulting in poorer carcase quality and varying growth performance;
- Changes in the amino acid requirements of the pig and amino acid availability through the increased presence of phytate consistent with an increase in fibre intake;
- Varying consumption of deep litter material relative to formulated feed increasing the variation in pig performance;
- Any combination of the above.

To better understand the extent of influence of the above factors, APL Project 1754 "Accurate assessment of diet intake and composition in various pig housing systems" was undertaken as a preliminary investigation to:

- Establish alkane profiles in straw (from two sources varying in quality), rice hulls and sawdust. Define a suitable alkane marker for addition to formulated feed.
- Identify the need to use alternative markers such as ytterbium acetate or bees wax with some deep litter materials in the event there is an absence of suitable alkane markers.
- Determine the faecal digestibility of a test diet and straw (from two sources varying in quality), rice hulls and sawdust.
- Correlate measured intake of spiked formulated diet/deep litter combinations with calculated intake.
- Apply alkane "fingerprints" and determine faecal digestibility values to measure the proportion of formulated diet consumed relative to straw, rice hulls and sawdust, respectively, in pigs in DL housing systems.

- Define the influence of deep litter material on consumption by pigs in DL housing systems.

Results from this preliminary research suggest that:

1. Pigs housed in DL systems consume a significant proportion of bedding material;

2. The extent of bedding material consumption varies by type;

3. Bedding material has a very low or negative influence on digestible energy content of the diet.

Consumption of Bedding Material in DL Systems

To demonstrate the magnitude of consumption of bedding material in DL systems, two hundred female pigs (commercial genotype; 22-25 kg) were allocated to two pens (100/pen) within a commercial deep litter shed, both containing rice hulls as the deep litter material. Pigs were offered a commercial grower diet that included 200 mg/kg of n-hexatriacontane (C-36) as an alkane marker. After a 7 d adaption period, faeces samples were collected from 10 pigs in each pen on day 8. Pigs were then removed from the pens, the bedding material replenished, the pigs randomly remixed (now at 25-30 kg) and the procedure repeated (total experimental period 16 d). Alkane profiles in the rice hulls, diet and faeces samples were determined by gas chromatography. Diet compositions were estimated by matching the alkane profiles of the faeces and diet components (grower diet, rice hulls) using the least-squares software package "Eat What" (Dove and Moore, 1995). Estimates were made with and without correction of faecal alkane concentrations for the incomplete recovery of alkanes of chain length <C36 or long chain alcohols (H. Dove, unpublished data). The results indicate that in all cases, there were detectable and at times appreciable quantities of bedding material in the diet of the pigs housed in DL systems, comprising up to 13% of the diet and averaging 8.9% of the diet across all pens (Table 1). The data also suggested differences in dietary proportions between bedding materials, between days of sampling, and as a consequence of applying a correction for incomplete faecal recovery of alkanes and long-chain alcohols (LCOH).

Table 1: Mean diet compositions (±SEM) for individual pens, in relation to bedding material and day of estimation

Bedding material	Pen	Day of estimation	Estimated % bedding material in diet[a]	Estimated % bedding material in diet[b]
Barley straw[c]	4	3	10.8 ± 2.69	12.3 ± 2.72
		6	12.6 ± 0.90	14.1 ± 0.91
	5	3	8.0 ± 0.83	9.5 ± 0.85
		6	9.2 ± 0.86	10.7 ± 0.87
Rice hulls[c]	8	3	4.2 ± 0.34	5.5 ± 0.36
		6	8.1 ± 0.91	9.5 ± 0.95
	9	3	4.5 ± 0.46	5.8 ± 0.48
		6	8.2 ± 0.53	9.7 ± 0.55
Sawdust[d]	2	3	0	1.2 ± 0.66
		6	7.4 ± 1.82	12.4 ± 2.44
	3	3	5.8 ± 2.77	8.9 ± 3.48
		6	1.2 ± 1.13	2.7 ± 1.75
Wheat straw[c]	6	3	11.9 ± 1.03	13.1 ± 1.06
		6	10.3 ± 1.60	11.4 ± 1.63
	7	3	6.4 ± 0.59	7.4 ± 0.61
		6	6.5 ± 0.92	7.5 ± 0.94

[a]Not corrected for incomplete faecal alkane/LCOH recovery.

[b]Corrected for incomplete faecal alkane/LCOH recovery.

[c]Diet composition estimated using odd-chain alkanes C25-C33 and alkane C36.

[d]Diet composition estimated using alkanes plus even-chain alcohols to C30OH

The results were subsequently examined by analysis of variance, with 'bedding material' and 'day of sampling' as treatment terms and 'pen' as the block term. A similar analysis of variance was conducted for the differences in dietary proportions estimated either with or without faecal recovery correction. When diet compositions were estimated without correction for incomplete faecal recovery of markers, the mean proportion of bedding material in the diet ranged from 3.6% (sawdust) to 10.1% (barley straw), with the difference in proportion between these materials being statistically significant ($P<0.05$, Table 2). The proportions of rice hulls or wheat straw in the diet were intermediate between the sawdust and barley straw and did not differ significantly from them.

Table 2: Results of analyses of variance of the effects of bedding material and day of measurement on the treatment mean content of bedding material in the diet

	Barley straw	Rice hulls	Sawdust	Wheat straw
% in diet (no correction)* (Day effect P<0.05)	10.1[b]	6.2[ab]	3.6[a]	8.8[ab]
% in diet (corrected)** (Day effect P<0.05)	11.6[a]	7.6[a]	6.3[a]	9.9[a]
Recovery increment (Day effect NS)	1.5[a]	1.4[a]	2.7[b]	1.1[a]

*No correction for incomplete faecal alkane/LCOH recovery.

**Corrected for incomplete faecal alkane/LCOH recovery.

[a,b]Values in a row followed by different letters differ significantly (P<0.05).

The overall mean proportion of bedding material in the diet was significantly higher on day 6 than on day 3 (7.9 v. 6.4%; P<0.05). A similar effect of sampling day was also evident in the proportions estimated after applying faecal recovery corrections (day 6, 9.8%; day 3, 8.0%; P<0.05). However, despite a similar pattern in dietary proportions between the different bedding materials, the differences between them were no longer significant. This reflects the fact that the effect of correcting for faecal marker recovery was significantly greater in the case of pigs on the sawdust bedding (P<0.05).

Influence of Bedding Material Intake on Diet Digestible Energy Content

It appears that the digestibility of the respective bedding materials is either very low, or has a negative impact on the digestibility of the other dietary ingredients when consumed at moderate levels. Samples of commercial grower diet were cold press- pelleted alone or combined with 20% wheat straw, barley straw, sawdust or rice hulls, respectively and digestible energy content determined using total faecal collection procedures. When the digestibility of the bedding materials is calculated, it appears that saw dust and rice hulls depress the digestible energy contribution from other diet components, whereas wheat and barley straw contribute approximately 1 MJ of DE/kg consumed (Table 3).

Table 3: Digestible energy content (MJ/kg DM) of sawdust, rice hulls, wheat straw and barley straw, respectively, determined by total faeces collection, calculation using coefficients or acid-insoluble ash.

Diet	Total collection
Sawdust	-0.41
Rice hulls	-1.04
Wheat straw	0.96
Barley straw	1.07

Consumption of the respective bedding materials resulted in a significant depression on the digestibility of gross energy, crude protein and dry matter (Table 4), which equates to a drop in total digestible energy supply to the pig of approximately 3 MJ/kg (Table 5).

Table 4: Energy, crude protein and dry matter digestibility coefficients (proportion of total) for a control grower diet and diets containing 20% sawdust, rice hulls, wheat straw or barley straw, respectively.

Diet	Energy	Crude protein	Dry matter
Control grower	0.83[a]	0.86[a]	0.81[a]
Grower + sawdust	0.65[b]	0.72[b]	0.65[b]
Grower + rice hulls	0.69[b]	0.76[b]	0.66[b]
Grower + wheat straw	0.67[b]	0.73[b]	0.66[b]
Grower + barley straw	0.69[b]	0.74[b]	0.67[b]

Table 5: Diet digestible energy content (MJ/kg, DM) for a control grower diet and diets containing 20% sawdust, rice hulls, wheat straw or barley straw, respectively, determined by total faeces collection, calculation using coefficients or acid-insoluble ash.

Diet	Total collection
Control grower	14.22
Grower + sawdust	11.01
Grower + rice hulls	10.88
Grower + wheat straw	11.28
Grower + barley straw	11.30

The above research was successful in demonstrating that pigs do in fact consume significant proportions of fresh bedding material, regardless of bedding material type, when housed in DL systems, and that the consumption of this bedding material increases over time. The data also demonstrates that consumed deep litter material dilutes the total digestible energy intake and the efficiency of digestion of other nutrients. Before remedial action can be taken to correct diet formulations to account for this consumption of bedding material, and based on the original hypothesis, further research is required to establish the upper limits of bedding material consumption by pigs housed in DL systems, accounting for the fact that fouling of the bedding material may restrict intake over time, the increase in *ad libitum* manufactured diet consumption resulting when pigs consume a proportion of their diet as bedding material and the influence of varying levels of bedding material consumption on the digestibility of other nutrients.

Nutritional Strategies to Minimise the Influence of Bedding Material Consumption on Growth Efficiency

With the changing nature of the Australian pig industry the location of experiments was not as stated in the project reference schedule. As a result of these changes in research infrastructure the proposed experimental designs were also modified.

Experiment 1: Upper Limits of Bedding Material Intake by Pigs Housed in Commercial Deep Litter Systems

Methodology

120 female pigs (commercial genotype; 15 to 100 kg) were allocated, blocked on live weight, to four pens (30 pigs per pen) prepared with either barley straw or sawdust bedding (n=2), with bedding material being replenished fortnightly as per standard practice. Pigs were fed two common diets throughout this period, a grower diet (14.3 MJ digestible energy (DE)/kg; 0.70 g available Lysine (AvL)/MJ DE) fed for the first 7 weeks (until exhaustion of a 10 t batch) and a finisher diet (13.5 MJ DE/kg; 0.56 g AvL/MJ DE) for the remaining six weeks.

Figure 1: Ecoshelter pens showing pen layout with sawdust (left) and straw (right) bedding.

Diets were supplemented with a C-36 alkane marker (n-hexatriacontane, 200 mg/kg, Sigma-Aldrich Pty Ltd, Castle Hill) to allow for determination of bedding material intake. Faecal samples were collected, from 10 random pigs per pen, four times throughout the growth period, at 3, 7, 11 and 13 weeks after the start of the project. Alkane profiles in the bedding material, diet and faeces were determined by gas chromatography (Dove and Mayes, 2006). Diet composition was estimated from the alkane profiles of the diets, bedding materials and faeces (*EatWhat*; Dove and Moore, 1995). Dunging patterns were also recorded. One way ANOVA (Genstat 10th edition, VSN International Ltd, Hemel Hempstead) was used to compare treatments. Where a significant effect was observed means were compared by least significant difference.

Results

Growth performance of pigs did not differ significantly as a result of bedding material, with no difference in total weight gain (Table 6) over the whole experimental period. There was a minor non-significant difference in feed intake that was also reflected in a marginally better feed conversion for those pigs housed on straw.

Table 6: Weights, feed intake and feed conversion ratio of pigs housed on sawdust or straw bedding.

	Start weight (kg)	End weight (kg)	Weight gain (kg)	Feed intake (kg)	FCR
Sawdust	15.7	103.0	87.2	204.2	2.35
Straw	15.8	103.0	87.2	200.0	2.30
SED	0.49	1.56	7.51	1.42	0.19
P value	0.931	0.989	0.995	0.097	0.801

Generally, average daily gain did not differ as a result of bedding material. Pigs grew significantly faster to week 7 when housed on sawdust (Table 7), which was a consistent trend across the weighing events.

Table 7: Average daily gain (ADG) of pigs housed on sawdust or straw bedding from start until weighing at week 3, 7, 11 and end.

	ADG week 3 (kg/d)	ADG week 7 (kg/d)	ADG week 11 (kg/d)	ADG end (kg/d)
Sawdust	0.987	0.865^{a}	0.912	0.948
Straw	0.961	0.833^{b}	0.885	0.948
SED	0.029	0.016	0.015	0.015
P value	0.372	0.042	0.070	0.993

^{a,b}Means in a column with different superscripts differ significantly (P<0.05)

As expected, during the grower phase, pigs ate significantly less than in the finisher phase (P=0.002; Table 8). The intake of bedding material was significantly affected by both bedding material and diet, and their interaction (P<0.001). Consumption of sawdust was very limited and accounted for less than 0.3 % of the total diet consumed by these pigs, whereas straw was readily consumed during both the grower and finisher phase, accounting for 5.2 % of the total diet consumed in the grower phase and 7.1 % in the finisher phase.

Table 8: The average daily intake (ADI) of formulated diet and bedding material, and the percentage of total diet that was consumed as bedding material.

Diet	Bedding	Diet ADI (kg/d)	Bedding ADI (g/d)	Bedding intake (% of diet)
Grower	Sawdust	2.08 ± 0.39^{a}	1.0 ± 1.0^{a}	0.05 ± 0.05^{a}
	Straw	2.05 ± 0.41^{a}	95.5 ± 7.9^{b}	5.15 ± 1.07^{b}
Finisher	Sawdust	3.25 ± 0.09^{b}	11.8 ± 11.4^{a}	0.28 ± 0.28^{a}
	Straw	3.20 ± 0.09^{b}	247.2 ± 15.0^{c}	7.08 ± 0.31^{c}
SED		0.411	14.48	0.815
P (bedding)		0.899	<0.001	<0.001
P (diet)		0.002	<0.001	0.087
P (inter)		0.966	<0.001	0.166

^{a,b,c}Means in a column with different superscripts differ significantly (P<0.05); SED, standard error of the difference between means; *P* (inter), significance of interaction between bedding and diet.

As the pigs grew and the diet feed intake increased so did the absolute amount of straw consumed (Figure 2), however the intake of sawdust did not occur or occurred to only a minor degree at any weight. This rise in straw intake appears to be a response to the diet rather than the weight of the animal. When bedding material intake was assessed as a percentage of the total diet intake (Figure 3), intake of bedding material was relatively static. Sawdust was not consumed to any significant degree, whilst, apart from the measure around 60 kg, cereal straw appears to be consumed in the diet at the level of seven % of the total diet intake.

The dunging pattern of pigs housed on sawdust tended to be more spread out than that of pigs housed on straw (Figure 4), especially in latter collections, however there was no significant effect of bedding material type on the percentage of bedding that was spoiled (Table 9). The percentage of bedding material spoiled within pens tended to increase with time, with a significantly larger percentage of sawdust bedding being spoiled in the third collection period than in previous collections on both materials.

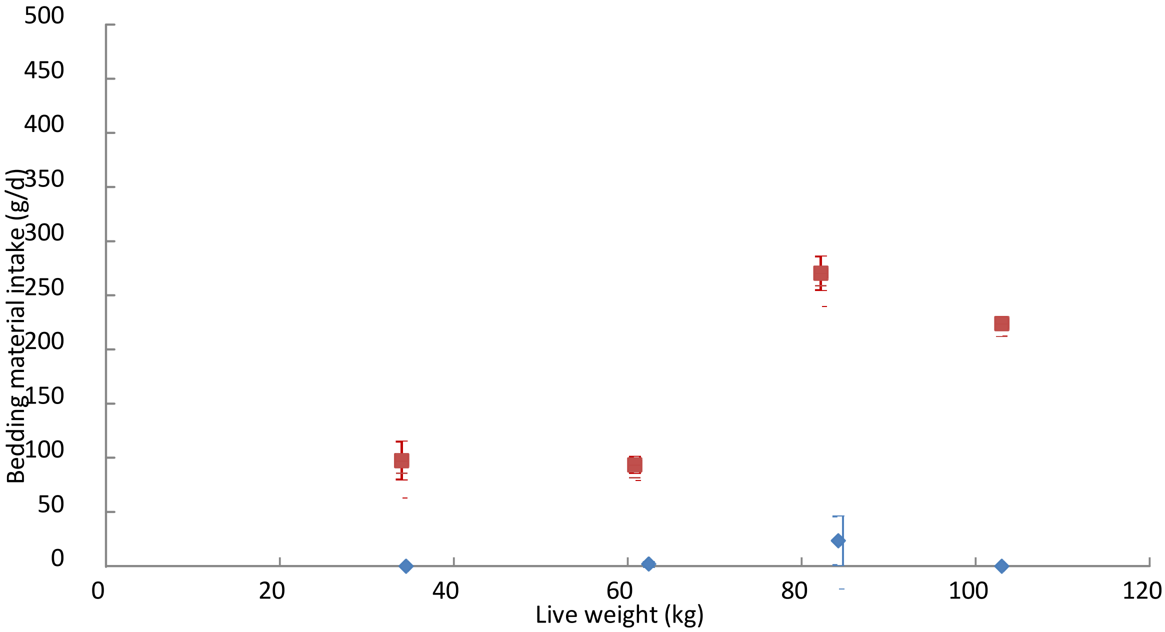

Figure 2: The average daily intake (g/d) of bedding material (straw, ■; sawdust, +), calculated by comparing faecal, diet and bedding material alkane concentrations at various live weights.

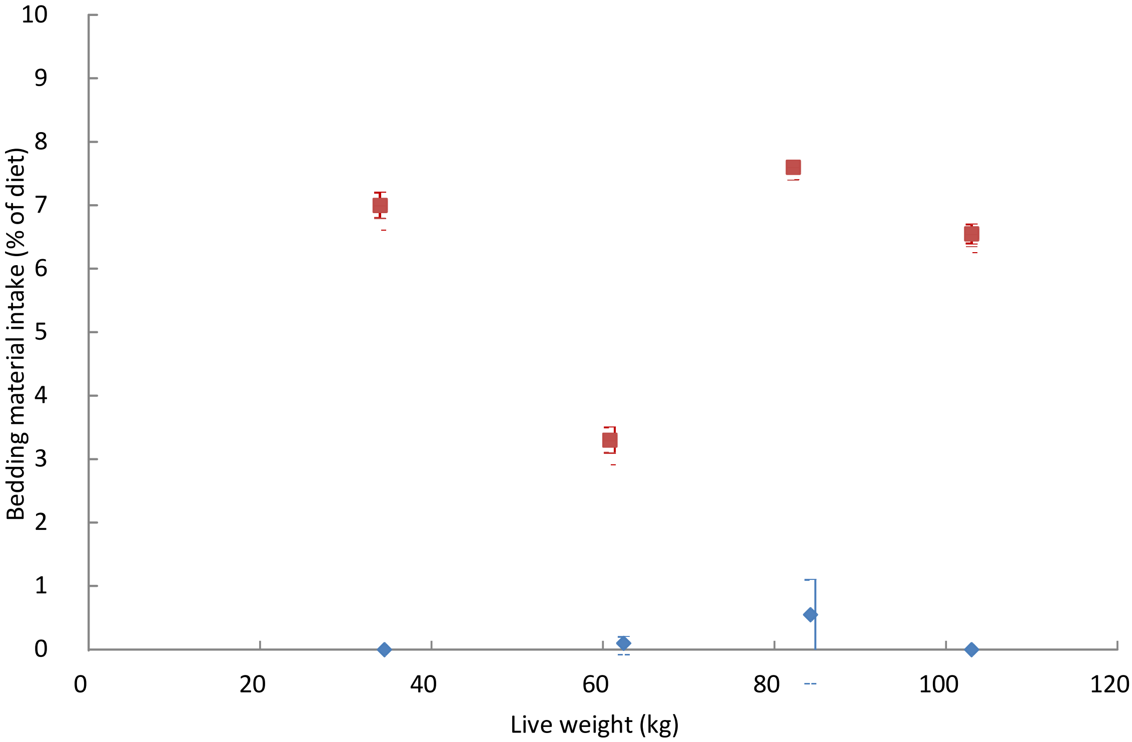

Figure 3: The average daily intake of bedding material (straw, ■; sawdust, +) as a proportion of the total diet consumed, calculated by comparing faecal, diet and bedding material alkane concentrations at various live weights.

Table 9: The average percentage of bedding material that was spoiled at the end of each collection for both sawdust and straw bedding.

Bedding	Collection	Spoiled Bedding (%)
Sawdust	1	13.5[a]
	2	13.9[a]
	3	28.2[b]
	4	21.1[ab]
Straw	1	10.1[a]
	2	11.6[a]
	3	18.5[ab]
	4	20.2[ab]
SED		0.06
P (bedding)		0.188
P (collection)		0.047
P (inter)		0.706

[a,b]Means in a column with different superscripts differ significantly ($P<0.05$); SED, standard error of the difference between means; *P* (inter), significance of interaction between bedding and collection.

Discussion

The type of bedding material present did not affect the growth of the pigs across the whole experiment although some differences in interval growth rates were observed with pigs housed on sawdust growing quicker during these periods. As would be expected finisher pigs ate more diet than grower pigs and ate more bedding on an absolute level. However, significantly more straw was consumed than sawdust, with a negligible amount of sawdust being consumed. It is likely that the source of sawdust in this experiment had an influence on its consumption due to the texture of the Karri/Jarrah hardwood mix available. Previous studies utilising softwood sawdust have shown significant levels of consumption.

The amount of bedding material consumed as a percentage of the total diet consumed appears to be consistent across time and weight, with approximately 7% of the total diet of pigs housed on cereal straw being that bedding material, and was not affected by the increased area of spoiled bedding as the pigs grew. This is a very significant finding. It means that formulated diet adjustments can be made and these adjustments will be applicable regardless of pig weight and degree of bedding material spoilage.

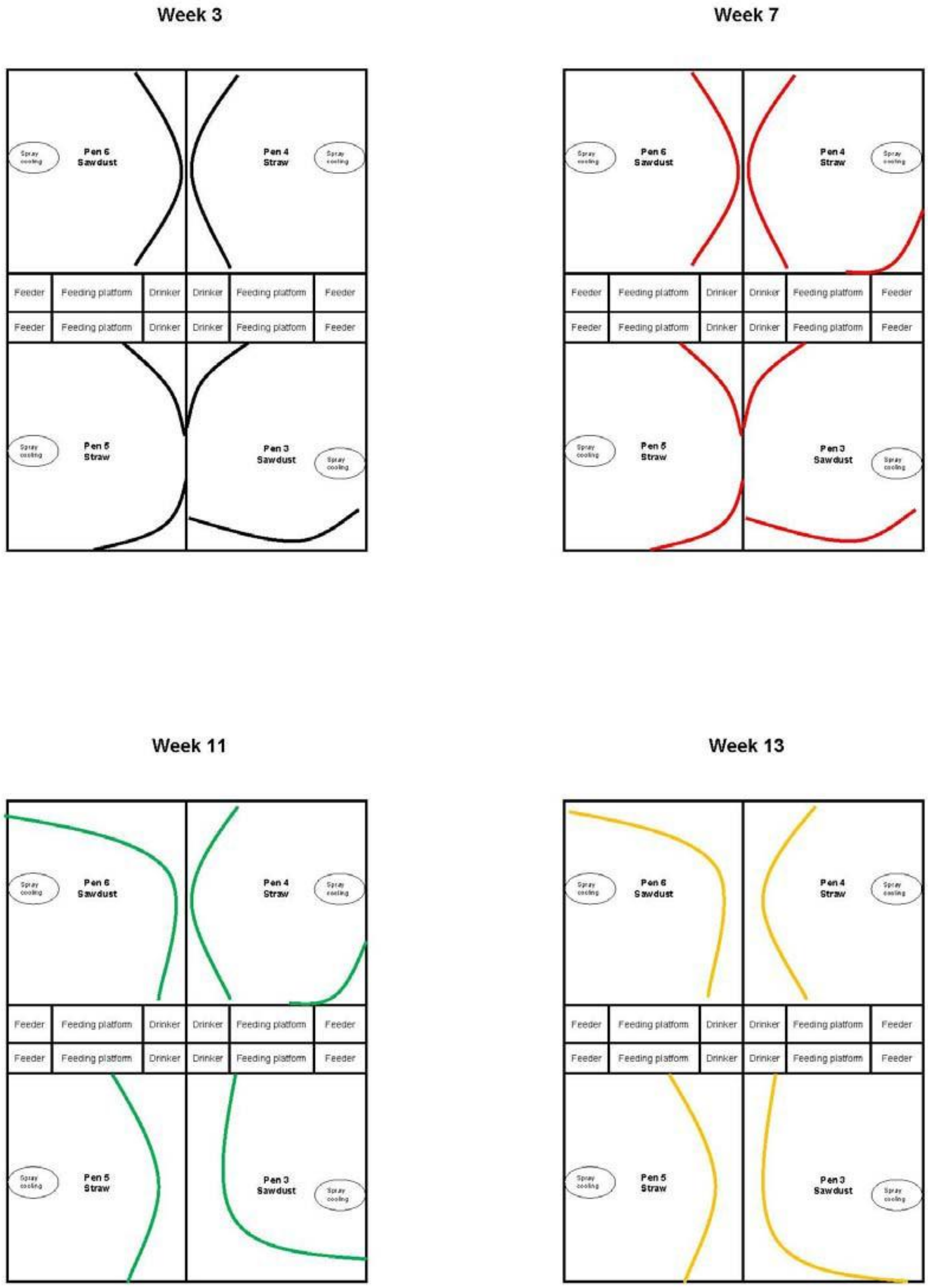

Figure 4: Changes in dunging patterns over the experimental period.

Experiment 2: Ad Libitum Intake of Formulated Diets by Pigs in Addition to Voluntary Consumption of Bedding Material

Consumption of deep litter material by pigs housed in deep-litter (DL) housing systems is thought to reduce the efficiency of nutrient utilisation and subsequent production efficiency. Previous research has shown that growing pigs consume between 6 and 12% of their diet as bedding material (depending on bedding material type) when housed in DL systems.

This experiment assessed the increase in *ad libitum* feed intake of a formulated diet when pigs were able to consume a proportion of their diet as bedding material and the subsequent impact on nutrient utilisation and performance parameters. Two additional treatments were included to assess the effects on consumption of bedding material and formulated diet when feed disturbances occur.

Methods

There were five feeding treatments to allow for the impact of consumption of bedding material to be defined. Three bedding material treatments were applied, a control group that received no bedding material and two groups that received either barley straw or rice hulls. Two feeding regimens were also applied, *ad libitum*, or an interrupted treatment where feed was offered *ad libitum* on day one and at half the amount consumed on day one on the subsequent day, with this two-day cycle continuing for the full 21 day feeding period. This resulted in the following treatment structure:

Treatment 1: No Bedding / A*d libitum* (Control)
Treatment 2: Barley straw bedding / *Ad libitum* feeding
Treatment 3: Barley straw bedding / Interrupted feeding Treatment 4: Rice hull bedding / A*d libitum* feeding
Treatment 3: Rice hull bedding / Interrupted feeding

Eight male pigs, 7-8 weeks of age (25 kg in weight) and of a commercial genotype were randomly allocated to each treatment. Pigs were housed in individual pens (40% solid and 60 % slatted) and grown from 25 to 90 kg liveweight at the Queensland Department of Primary Industries and Fisheries Wacol Pig Research Centre over a period of 9 weeks. The solid concrete section of each pen was cordoned off (0.8 x1.2 m^2) to contain the bedding material which was supplied fresh on a daily basis to a depth of 4 cm. From 25-61 kg pigs in all treatments were fed a commercial pelleted grower diet (13.9 MJ DE/kg, 0.84 g AvL/MJ DE; Table 10) and from 61 kg onwards they were fed a commercial pelleted finisher diet (13.5 MJ DE/kg, 0.68 g AvL/MJ DE; Table 10) until the end of the experiment. Both the grower and the finisher diet were spiked with 200 mg/kg of the marker n-hexatriacontane (C-36) so that the intake of fresh bedding material could be measured relative to formulated feeds through comparison with natural alkanes and long-chain alcohols in the respective bedding materials.

Table 10: Composition of commercial grower and finisher diets (%).

Diet	Grower	Finisher
Barley	0.0	28.9
Sorghum	49.9	49.5
Wheat	10.8	0.0
Millrun	10.0	0.0
Canola meal	10.0	10.0
Soybean meal	6.8	5.03
Full fat soybean meal	3.3	0.0
Meat meal	7.3	3.03
Vegetable oil	1.0	1.0
Salt	0.2	0.3
Dicalphos	0.0	1.0
DL methionine	0.04	0.007
Lysine HCL	0.36	0.3
L-threonine	0.01	0.0
Choline chloride	0.0	0.007
Pig grower premix	0.15	0.15
DP	20.2	16.8
DE (MJ/kg)	13.9	13.5
Available lysine/DE	0.84	0.68

Faecal samples were collected weekly for alkane analysis to facilitate measurement of bedding material. *Ad libitum* intake of the commercial diet was measured daily and was related to mean weekly bedding material intake to establish mean daily DE intake. Live weights were recorded on a weekly basis as well as at the start and end of the experiment to determine growth rates. Alkane profiles in the bedding material, diet and faeces were determined by gas chromatography (Dove and Mayes, 2006). Diet composition was estimated from the alkane profiles of the diets, bedding materials and faeces (*EatWhat*; Dove and Moore, 1995).

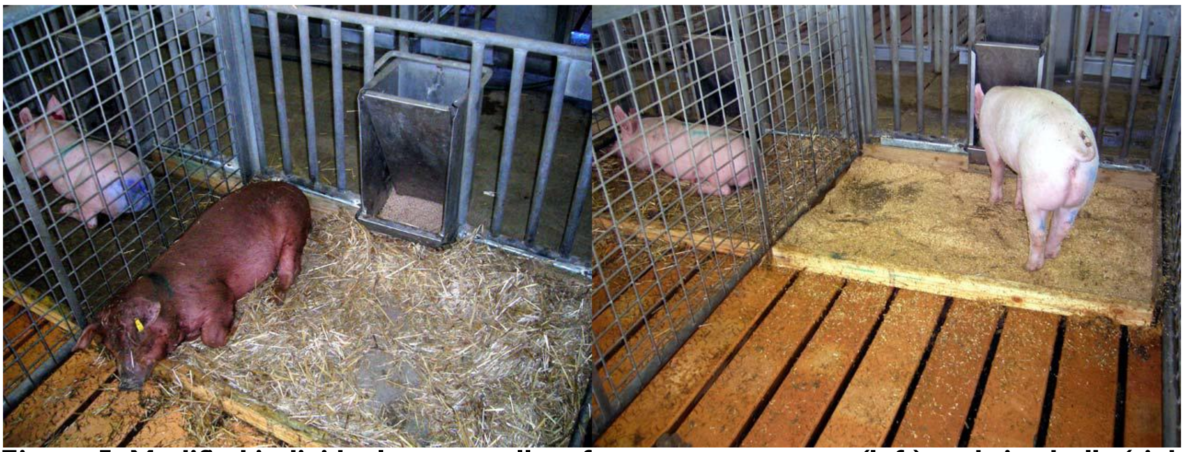

Figure 5: Modified individual pens to allow free access to straw (left) and rice hulls (right).

One way ANOVA (Genstat 10th edition, VSN International Ltd, Hemel Hempstead) was used to compare all 5 treatments to determine if the provision of bedding material and restricted feed supply had an effect on average daily gain (ADG), total feed intake and FCR. Where a significant effect was observed means were compared by least significant difference. All data was checked for normality and homogeneity of variances which was the case.

Results

One pig from treatment 5 was euthanized on day 3 of week 4 with a chronic ulcer. No other mortalities occurred. The access to bedding material in grower pigs resulted in an increase in average daily gain, when fed *ad libitum* (Table 11), however, with feed interruption growth rates were closer to the control treatment. Average daily feed intake was not affected by the inclusion of bedding material, but was depressed by interruption to feed. As a consequence, there was a trend for feed conversion to be improved when bedding material was made available, and the access to bedding material offset some of the effects of feed interruption.

In finisher pigs access to bedding material resulted in an increase in feed intake, however this effect was offset by feed interruption (Table 12). Whilst there was a trend for pigs fed *ad libitum* with access to bedding material to grow faster than the control or interrupted treatments, it was not significant, whilst feed conversion was unchanged between treatments.

Table 11: Average start and end weight, average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) of grower pigs offered bedding material and subjected to an *ad libitum* or interrupted feeding regimen.

Bedding	Feeding	Start wt (kg)	End wt (kg)	ADG (kg/d)	ADFI (kg/d)	FCR
Nil	*Ad libitum*	28.7	60.7^{ab}	0.887^{ab}	1.96^{bc}	2.21
Barley straw	*Ad libitum*	29.0	63.7^{b}	0.962^{bc}	2.00^{c}	2.09
Barley straw	Interrupted	28.8	59.2^{a}	0.844^{a}	1.80^{ab}	2.14
Rice hulls	*Ad libitum*	28.7	64.2^{b}	0.988^{c}	2.03^{c}	2.05
Rice hulls	Interrupted	28.8	58.7^{a}	0.833^{a}	1.74^{a}	2.10
SED		1.03	2.22	0.046	0.097	0.072
P value		0.997	0.049	0.004	0.017	0.288

a,b,cMeans in a column with different superscripts differ significantly (P<0.05)

Table 12: Average start and end weight, average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) of finisher pigs offered bedding material and subjected to an *ad libitum* or interrupted feeding regimen.

Bedding	Feeding	Start wt (kg)	End wt (kg)	ADG (kg/d)	ADFI (kg/d)	FCR
Nil	*Ad libitum*	60.7^{ab}	85.7^{ab}	1.195	2.80^{ab}	2.38
Barley straw	*Ad libitum*	63.7^{b}	90.6^{b}	1.282	3.00^{b}	2.35
Barley straw	Interrupted	59.2^{a}	83.7^{a}	1.167	2.69^{a}	2.34
Rice hulls	*Ad libitum*	64.2^{b}	90.3^{b}	1.242	2.90^{ab}	2.34
Rice hulls	Interrupted	58.7^{a}	83.9^{a}	1.196	2.69^{a}	2.27
SED		2.22	3.05	0.075	0.106	0.118
P value		0.049	0.057	0.561	0.020	0.931

a,bMeans in a column with different superscripts differ significantly (P<0.05)

Over the whole growth period (Table 13) the average daily feed intake of pigs with access to bedding material when fed *ad libitum* was increased, whilst interruption decreased feed intake (as expected). The growth rate response of pigs over the whole experiment was more strongly affected by feed interruption than by the inclusion of bedding material, with no significant differences in feed conversion being observed.

Grower pigs did not ingest significant amounts of bedding material (Table 14) and ingestion patterns were not consistent, whilst pigs that had an interrupted feeding pattern ate more barley straw, they consumed less rice hulls. However, in finisher pigs there was a strong significant difference between treatments with barley straw making up four to 5% of the total diet of pigs with access to this bedding material, whilst those pigs with access to rice hulls consumed up to 14 % of their diet as rice hulls.

Table 13: Average start and end weight, average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) of grow-finisher pigs offered bedding material and subjected to an *ad libitum* or interrupted feeding regimen.

Bedding	Feeding	Start wt (kg)	End wt (kg)	ADG (kg/d)	ADFI (kg/d)	FCR
Nil	*Ad libitum*	28.7	85.7^{ab}	1.000^{ab}	2.27^{bc}	2.27
Barley straw	*Ad libitum*	29.0	90.6^{b}	1.080^{b}	2.37^{c}	2.20
Barley straw	Interrupted	28.8	83.7^{a}	0.963^{a}	2.13^{ab}	2.22
Rice hulls	*Ad libitum*	28.7	90.3^{b}	1.082^{b}	2.35^{c}	2.17
Rice hulls	Interrupted	28.8	83.9^{a}	0.967^{a}	2.09^{a}	2.18
SED		1.03	3.05	0.045	0.086	0.076
P value		0.997	0.057	0.017	0.005	0.683

^{a,b,c}Means in a column with different superscripts differ significantly (P<0.05)

Table 14: Estimated content of bedding material (% of diet) in the total diet of grow-finisher pigs offered bedding material and subjected to an *ad libitum* or interrupted feeding regimen.

Bedding	Feeding	Grower	Finisher
Nil	*Ad libitum*	-	-
Barley straw	*Ad libitum*	1.2^{a}	4.1^{a}
Barley straw	Interrupted	2.5^{b}	5.2^{a}
Rice hulls	*Ad libitum*	1.8^{ab}	14.2^{b}
Rice hulls	Interrupted	1.1^{a}	13.3^{b}
P value		0.040	<0.001

^{a,b}Means in a column with different superscripts differ significantly (P<0.05)

The low intake of bedding material in grower pigs was reflected in only minor changes in whole-diet digestibility (Table 15); however, the higher intakes in finisher pigs resulted in a 5% reduction in digestibility, irrespective of bedding material and the level of intake.

Table 15: Estimated whole-diet digestibility (%) in grow-finisher pigs offered bedding material and subjected to an *ad libitum* or interrupted feeding regimen.

Bedding	Feeding	Grower	Finisher
Nil	*Ad libitum*	82.6	84.8^{a}
Barley straw	*Ad libitum*	80.4	79.7^{b}
Barley straw	Interrupted	79.6	79.5^{b}
Rice hulls	*Ad libitum*	81.5	79.6^{b}
Rice hulls	Interrupted	81.8	80.0^{b}
P value		0.345	<0.001

^{a,b}Means in a column with different superscripts differ significantly (P<0.05)

Discussion

Results from this experiment suggest that the provision of bedding material, whether it is rice hulls or barley straw, has no effect on average daily gain, feed intake or FCR in pigs fed *ad libitum*. However, if there are interruptions in feed supply daily gain may be reduced significantly. It should be mentioned that these results only pertain to male pigs supplied with rice hulls or barley straw as bedding and grown from 25- 90 kg. No inference can be made regarding the effects of other types of bedding material or size class and gender of pigs. It is also reasonable to assume that increased gut fill in pigs with access to bedding material may be influencing the results.

The results of the alkane analyses show a strong preference to consume rice hulls compared with barley straw. This would appear to be a response to the form of the bedding material. Interruption of feed supply was, somewhat surprisingly, not a major factor in the intake of bedding material over the course of the experiment – whilst it was not measured, there may have been a cyclical effect on a day-to-day basis as one would have expected hunger to result in greater consumption of bedding material. The major implication of this experiment is the finding that no matter what the bedding material was, nor the difference in consumption level, its effect on whole-diet digestibility was consistent. The results of this experiment suggest that diets for pigs housed in deep-litter systems should be up-specified to take account of this reduced digestibility.

Experiment 3: Quantification of the Effect of Bedding Material Intake on the Digestibility of Other Dietary Nutrients

Consumption of bedding material (straw, rice hulls, etc) by pigs may reduce overall nutrient and energy digestibility as well as diluting total digestible energy intake. To ensure accurate formulation of diets for pigs housed with bedding material, quantitative information on the energy and nutrient diluting effects of bedding material intake is required. This will enable any nutrient diluting effects to be corrected for in diet formulation so that the pig's nutrient requirements can be met. The aim of this experiment was to assess the effect of consumption of varying levels of bedding material by growing pigs on the ileal and faecal digestibility of gross energy, the ileal digestibility of lysine and the resulting digestible lysine:digestible energy ratio of the entire diet.

Methods

A basal grower diet formulated to contain 14.3 MJ digestible energy (DE) and 0.69 g of available lysine: MJ DE was used as a control (Table 16). Celite was included in the diet as an acid-insoluble ash marker. Rice hulls and chaffed barley straw were added to the basal diet at levels of 5, 10 or 15 % respectively, based on the upper level of bedding material intake reported by van Barneveld *et al.* (2003), to create 7 diets in total.

Seven male pigs (commercial genotype; 35 kg liveweight) were fitted with simple T- piece cannulas 15 cm anterior to the ileo-caecal valve as described by van Barneveld (1993) with the exception that skin barriers for use around stoma in human ileostomy patients (Stomahesive® System 2 with 70mm flange; Bristol-Myers Squibb, Princeton, NJ, 08543-4000 USA) were incorporated between the flange of the cannula and the skin to promote healing of the wound and to prevent any leakage around the cannula. Following a seven day surgery recovery period pigs were individually housed and randomly allocated to one of the seven diets. They were fed *ad libitum* for 5 days, followed by two days of digesta and faecal collection over an 8 hour period each day. Following the two days of faecal collection each pig was randomly assigned another of the seven diets which they were fed for 5 days, followed by two days of faecal collection. This procedure was repeated until each pig had received each of the seven diets.

Table 16: Composition of basal grower diet (%)

Ingredient	Grower
Sorghum	41.6
Wheat	25.5
Millrun	7.65
Canola meal	3.05
Soybean meal	10.2
Meat meal	7.15
Blood meal	2.00
Vegetable oil	2.00
Salt	0.05
DL methionine	0.05
Lysine HCL	0.30
L-threonine	0.05
Choline chloride	0.05
Mycofix*	0.10
Pig grower premix	0.15
DP	20.9
DE (MJ/kg)	14.3
Available lysine:DE	0.69

* Mycotoxin binder supplied by Biomin

Ileal digesta was collected directly onto ice prior to bulking and freezing. Faeces were collected as voided, bulked and frozen. All samples were analysed by the Queensland Department of Primary Industries and Fisheries for dry matter, nitrogen, gross energy, calcium, phosphorous, acid insoluble ash and amino acids to enable the calculation of ileal and faecal digestibility.

Data were analysed by one-way ANOVAs (Genstat 10th edition, VSN International Ltd, Hemel Hempstead) to determine if there were significant differences among treatments in ileal and faecal dry matter, nitrogen, gross energy, calcium, phosphorous and amino acid digestibility. Where a significant effect was observed means were compared by least significant difference. All data was checked for normality and homogeneity of variances which was the case.

Figure 6: Metabolism crates containing cannulated pigs during ileal digesta collection.

Results

The measured gross energy content of the diet was 18.76 MJ/kg (Table 17). While the addition of rice hulls caused the gross energy content of the diet to decline with increasing inclusion level, all diets with barley straw, regardless of inclusion level, had a higher gross energy content than the control diet containing no bedding material. The measured protein content of the control diet was 23.81 % (Table 15). Crude protein content of the diet decreased with increasing inclusion level of both rice hulls and barley straw.

Table 17: Gross energy and crude protein content of diets.

Diet	Gross energy (MJ/kg)	Crude protein (%)
Control (no bedding)	18.76	23.81
5 % Rice hulls	18.70	22.44
10 % Rice hulls	18.51	22.69
15 % Rice hulls	18.09	20.88
5 % Barley straw	19.03	22.69
10 % Barley straw	18.85	21.31
15 % Barley straw	18.82	20.69

Consumption of rice hulls and barley straw by growing pigs at levels of 5% had no significant effect on the ileal digestibility of gross energy ($P>0.05$), but energy digestibility was significantly depressed at consumption levels of both bedding materials when included at 10% and above (Table 18). The reduction in ileal gross energy digestibility resulting from 10% inclusion of rice hulls caused the ileal DE content of the diet to reduce from 12.3 MJ DE/ kg to 11.6 MJ DE / kg (Figure 5). In comparison, the reduction in ileal gross energy digestibility resulting from a 10% inclusion of barley straw caused the ileal DE content of the diet to reduce from 12.3 MJ DE/ kg to 10.6 MJ DE / kg (Figure 7).

A significant depression in faecal gross energy digestibility was observed for both rice hulls and barley straw at all inclusion levels (Table 18). The reduction in faecal gross energy digestibility resulting from 5% inclusion of rice hulls caused the faecal DE content of the diet to reduce from 14.7 MJ DE/ kg to 13.7 MJ DE / kg (Figure 7). In comparison, the reduction in faecal gross energy digestibility resulting from a 5% inclusion of barley straw caused the faecal DE content of the diet to reduce only slightly from 14.7 MJ DE/ kg to 14.5 MJ DE / kg (Figure 7).

Table 18: Ileal and faecal digestibility of gross energy in diets containing 0, 5, 10 or 15% rice hulls or barley straw, respectively.

Bedding material	Ileal		Faecal	
inclusion rate (%)	Rice hulls	Barley straw	Rice hulls	Barley straw
0	73.6[a]	73.6[a]	87.8[a]	87.8[a]
5	70.1[ab]	70.6[a]	83.0[b]	84.7[b]
10	68.8[b]	63.4[b]	80.1[c]	79.4[c]
15	63.8[c]	57.2[b]	73.9[d]	77.6[d]
SEM	2.13	3.40	0.63	1.44
P value	<0.010	<0.001	<0.001	<0.001

[a,b,c]Means in a column with different superscripts differ significantly ($P<0.05$); SEM, standard error difference of the mean.

Consumption of rice hulls by growing pigs had no effect on the ileal digestibility of protein at any of the inclusion levels investigated ($P>0.05$; Table 19). Consumption of barley straw had no effect on ileal protein digestibility at 5% but at an inclusion level of 10% and above it significantly reduced ileal protein digestibility. The reduction in ileal protein digestibility resulting from a 10% inclusion of barley straw caused the ileal DP content of the diet to reduce from 16.3 % to 14.0 % (Figure 8).

A significant depression in faecal protein digestibility was observed with the inclusion of 5% rice hulls and 10% barley straw (Table 19). The reduction in faecal protein digestibility resulting from a 5% inclusion of rice hulls caused the faecal DP content of the diet to reduce from 18.2 % to 15.9 % (Figure 8). In comparison, the reduction in faecal gross energy digestibility resulting from a 10% inclusion of barley straw caused the faecal DP content of the diet to reduce from 18.2 % to 15.6 % (Figure 8).

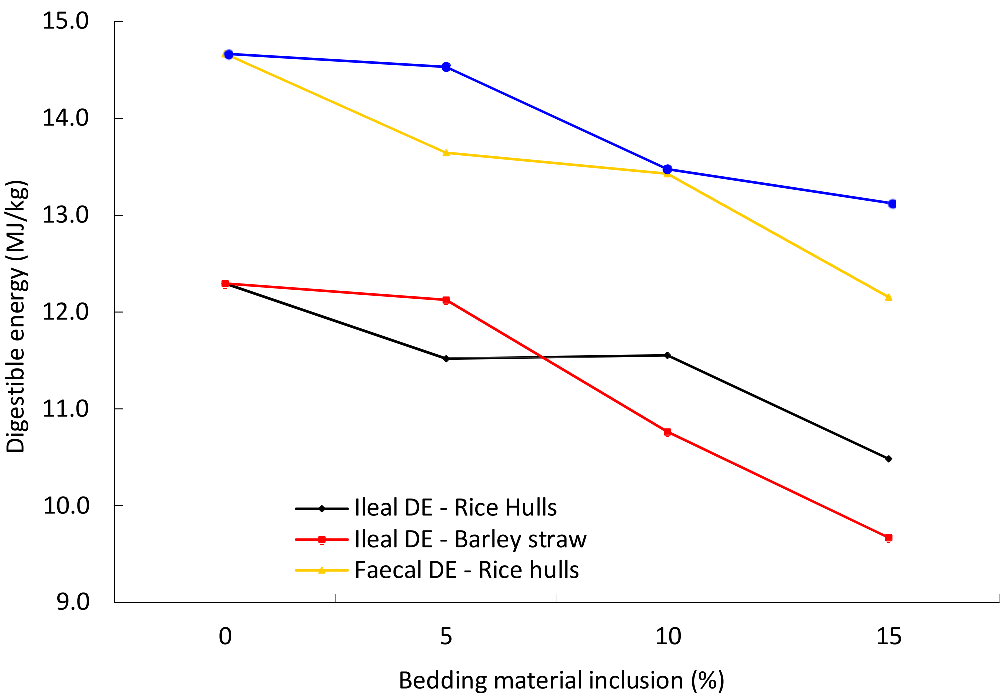

Figure 7: Reduction in ileal and faecal digestible energy content of the diet with increasing inclusion level of either rice hulls or barley straw.

Table 19: Ileal and faecal digestibility of protein in diets containing 0, 5, 10 or 15% rice hulls or barley straw, respectively.

Bedding material inclusion rate (%)	Ileal		Faecal	
	Rice hulls	Barley straw	Rice hulls	Barley straw
0	77.0	77.0^{a}	85.8^{a}	85.8^{a}
5	73.3	78.3^{a}	81.0^{b}	84.0^{ab}
10	74.3	73.0^{ab}	81.7^{b}	81.5^{c}
15	73.9	68.3^{b}	81.4^{b}	78.8^{c}
SEM	3.15	3.43	1.42	1.29
P value	0.665	0.039	0.012	<0.001

^{a,b,c}Means in a column with different superscripts differ significantly (P<0.05); SEM, standard error difference of the mean.

Besides proline and glutamic acid, the ileal digestibility of all amino acids were significantly reduced with the addition of just 5% rice hulls (Table 20). With regards to glutamic acid a significant reduction in digestibility occurred with 10% rice hull inclusion whilst with proline a significant reduction was observed only after 15 % inclusion of rice hulls. A similar response was observed with faecal amino acid digestibility with a significant reduction occurring in all amino acids except cystine after the inclusion of just 5% rice hulls. With cystine a reduction occurred with a 10% inclusion of rice hulls.

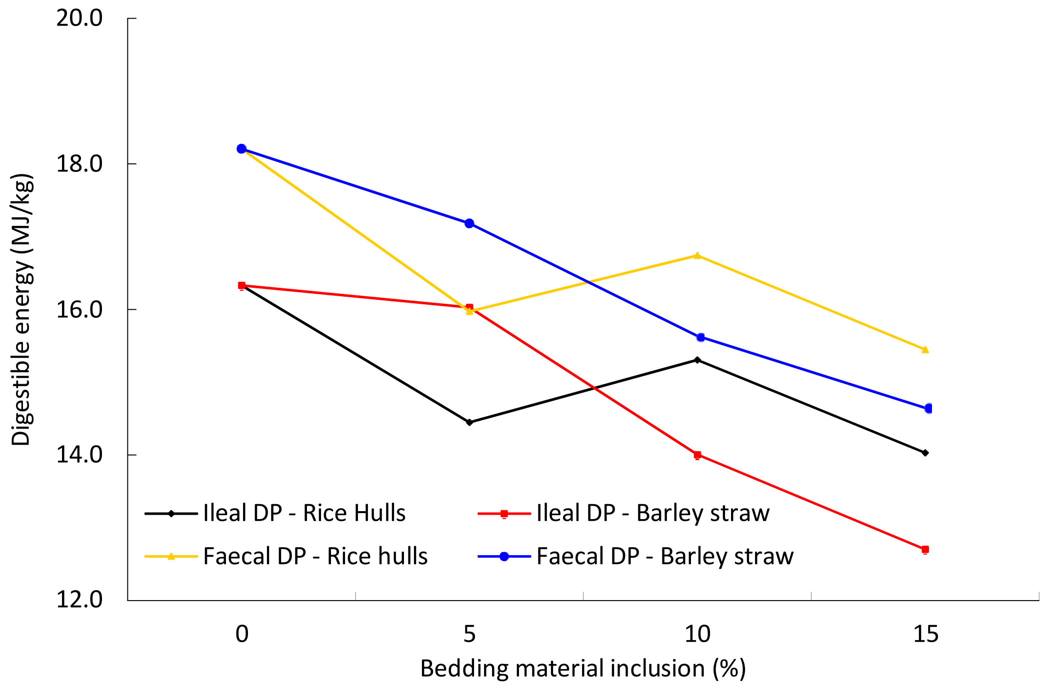

Figure 8: Reduction in ileal and faecal digestible protein content of the diet with increasing inclusion level of either rice hulls or barley straw.

Barley straw did not affect ileal and faecal amino acid digestibility to the same extent as rice hulls (Table 21). Generally, ileal and faecal amino acid digestibility was not significantly reduced until 10% barley straw was added to the diet. The ileal digestibility of proline and the faecal digestibility of cystine were unaffected by any inclusion level of barley straw (P>0.05).

Faecal lysine in the control diet was 89.0 % digestible. Its digestibility reduced to 83.9% with the inclusion of 5% rice hulls and to 86.9 % with the inclusion of 5% barley straw (Tables 20 & 21). Based on the dietary lysine levels measured in each of these diets this equates to faecal digestible lysine contents ranging from 11.37 g/kg in the control diet to 9.04 g/kg in the 5% rice hull diet and 10.05 g/kg in the 5% barley straw diet. The corresponding faecal digestible energy contents of these diets were 14.7 MJ DE/kg for the control diet, 13.7 MJ DE/kg for the 5% rice hull diet and 14.5 MJ DE/kg for the 5% barley straw diet (Figure 7). Thus, the inclusion of just 5% rice hulls or 5% barley straw in the diet changes the faecal digestible lysine to energy ratio of the control diet from 0.77 g digestible lysine:MJ DE to 0.66 g digestible lysine:MJ DE or 0.69 g digestible lysine:MJ DE, respectively.

Consumption of rice hulls by growing pigs had no effect on the ileal digestibility of protein at any of the inclusion levels investigated (P>0.05; Table 19). Consumption of barley straw had no effect on ileal protein digestibility at 5% but at an inclusion level of 10% and above it significantly reduced ileal protein digestibility. The reduction in ileal protein digestibility resulting from a 10% inclusion of barley straw caused the ileal DP content of the diet to reduce from 16.3 % to 14.0 % (Figure 8).

Much greater variability was observed between replicates for both ileal and faecal phosphorous and calcium digestibility than for the other parameters measured. The inclusion of barley straw had a lower effect on calcium digestibility than rice hulls with 10% barley straw significantly reducing faecal digestibility (P<0.05) and no effect of barley straw inclusion being observed on ileal digestibility (P>0.05; Table 22). In comparison, the inclusion of 5% rice hulls significantly reduced both the ileal and faecal digestibility of calcium (P<0.05; Table 22).

Phosphorous digestibility, both ileal and faecal, was less affected by the inclusion of rice hulls and barley straw in the diet than calcium digestibility (Table 22). Only the faecal digestibility of phosphorous was significantly reduced with the inclusion of 5% rice hulls (P<0.05). Higher consumption levels of rice hulls did not result in further reduction in faecal phosphorous digestibility. Ileal digestibility of phosphorous was unaffected by the inclusion of either rice hulls or barley straw whilst faecal digestibility of phosphorous was unaffected by the inclusion of barley (P>0.05).

Discussion

The consumption of bedding material, both rice hulls and barley straw, significantly reduced the digestibility of several nutrients from a basal grower diet for male pigs when included at levels ranging from 5 to 15 %. In general, ileal amino acid digestibility, faecal energy and faecal protein digestibility were affected when as little as 5% rice hulls and 5% barley straw were included in the basal diet. In addition, ileal and faecal calcium digestibility, faecal protein and faecal phosphorous digestibility were also significantly reduced with 5% rice hull inclusion.

Table 20: Ileal and faecal digestibility of amino acids in diets containing 0, 5, 10 or 15 % rice hulls, n=7.

	Bedding material inclusion (%)					
Treatment	0	5	10	15	SEM	P value
Ileal						
Alanine	89.5[a]	85.5[b]	85.1[b]	80.7[c]	1.177	<0.001
Arginine	93.2[a]	90.8[b]	90.4[b]	87.8[c]	0.753	0.001
Aspartic acid	87.9[a]	83.4[b]	82.1[b]	77.4[c]	1.348	<0.001
Cystine	87.4[a]	83.8[b]	79.1[c]	76.8[c]	1.022	<0.001
Glutamic acid	92.8[a]	89.9[ab]	88.8[b]	85.1[c]	1.122	0.001
Histidine	91.2[a]	88.2[b]	86.9[bc]	84.8[c]	0.907	<0.001
Isoleucine	91.7[a]	88.8[b]	87.3[bc]	84.8[c]	0.883	<0.001
Leucine	92.2[a]	89.3[b]	88.7[bc]	86.2[c]	0.883	0.002
Lysine	94.8[a]	92.5[b]	91.7[b]	88.9[c]	0.627	<0.001
Methionine	94.6[a]	92.7[b]	90.4[c]	90.5[c]	0.511	<0.001
Phenylalanine	92.3[a]	89.6[b]	88.8[b]	86.1[c]	0.753	<0.001
Proline	89.1[a]	84.4[a]	84.9[a]	77.0[b]	2.22	0.010
Serine	89.9[a]	86.7[b]	83.9[bc]	81.6[c]	0.985	<0.001
Threonine	89.2[a]	85.5[b]	83.2[b]	79.9[c]	0.993	<0.001
Tryptophan	85.5[a]	80.9[b]	80.0[bc]	76.6[c]	0.975	<0.001
Tyrosine	92.7[a]	90.1[b]	89.1[bc]	87.0[c]	0.764	<0.001
Valine	90.3[a]	86.8[b]	85.6[b]	82.3[c]	0.945	<0.001
Glycine	84.4[a]	78.7[b]	78.2[b]	72.1[c]	1.819	0.002
Faecal						
Alanine	85.7[a]	81.1[b]	81.6[b]	81.3[b]	1.128	0.032
Arginine	89.7 [a]	86.7[b]	87.3[b]	86.4[b]	0.737	0.022
Aspartic acid	85.6[a]	80.0[b]	79.5[b]	79.2[b]	1.040	0.001
Cystine	84.0[a]	82.4[a]	80.1[ab]	77.0[b]	1.510	0.026
Glutamic acid	92.5[a]	89.3[b]	88.6[b]	88.2[b]	0.697	0.002
Histidine	88.5[a]	85.1[b]	85.5[b]	85.5[b]	0.800	0.025
Isoleucine	84.8[a]	80.3[b]	80.6[b]	80.4[b]	1.085	0.025
Leucine	88.1[a]	84.6[b]	85.2[b]	85.1[b]	0.924	0.066
Lysine	89.0[a]	83.9[b]	84.1[b]	82.7[b]	0.889	<0.001
Methionine	84.7[a]	82.7[b]	80.9[b]	79.0[b]	1.815	0.177
Phenylalanine	87.4[a]	83.8[b]	84.0[b]	83.6[b]	0.912	0.029
Proline	90.5[a]	87.6[b]	87.3[bc]	85.6[c]	0.668	<0.001
Serine	87.4[a]	83.8[b]	83.3[b]	83.3[b]	0.860+0	0.009
Threonine	84.6[a]	79.2[b]	79.9[b]	79.1[b]	1.063	0.005
Tryptophan	83.8[a]	78.6[b]	80.7[b]	80.0[b]	0.960	0.009
Tyrosine	85.0[a]	81.2[b]	81.8[b]	82.2[ab]	1.072	0.094
Valine	85.2[a]	80.5[b]	81.5[b]	80.6[b]	1.058	0.018
Glycine	86.7[a]	82.3[b]	83.7[b]	81.8[b]	0.986	0.012

[a,b,c]Means within a row with different superscripts differ significantly (P<0.05)

Table 21: Ileal and faecal digestibility of amino acids in diets containing 0, 5, 10 or 15 % barley straw, n=7.

Treatment	Bedding material inclusion (%)				SEM	P value
	0	5	10	15		
Ileal						
Alanine	89.5[a]	89.2[a]	86.2[b]	86.4[b]	0.709	0.005
Arginine	93.2[a]	93.5[a]	91.6[b]	90.9[b]	0.564	0.010
Aspartic acid	87.9[a]	87.1[a]	83.7[b]	83.4[b]	0.864	0.002
Cystine	87.4[a]	87.1[a]	83.1[b]	83.2[b]	0.715	<0.001
Glutamic acid	92.8[a]	92.6[a]	90.5[b]	91.0[b]	0.549	0.018
Histidine	91.2[ab]	91.8[a]	89.4[c]	89.6[bc]	0.587	0.022
Isoleucine	91.7[a]	91.5[a]	88.5[b]	88.4[b]	0.572	<0.001
Leucine	92.2[a]	92.2[a]	90.1[b]	90.2[b]	0.535	0.013
Lysine	94.8[a]	95.1[a]	92.8[b]	93.2[b]	0.500	0.009
Methionine	94.6[a]	94.9[a]	92.7[b]	93.2[b]	0.391	0.002
Phenylalanine	92.3[a]	92.4[a]	90.3[b]	90.3[b]	0.481	0.005
Proline	89.1	87.6	84.6	82.2	2.12	0.128
Serine	89.9[a]	89.4[a]	86.1[b]	85.2[b]	0.598	<0.001
Threonine	89.2[a]	88.9[a]	84.1[b]	83.6[b]	0.686	<0.001
Tryptophan	85.5[a]	86.3[a]	78.9[b]	78.0[b]	1.297	<0.001
Tyrosine	92.7[a]	92.8[a]	90.3[b]	90.4[b]	0.468	<0.001
Valine	90.3[a]	90.1[a]	87.4[b]	86.8[b]	0.638	0.001
Glycine	84.4[a]	84.0[a]	78.7[b]	77.5[b]	1.172	<0.001
Faecal						
Alanine	85.7[a]	83.3[ab]	81.6[bc]	79.1[c]	1.506	0.003
Arginine	89.7[a]	88.5[a]	86.3[b]	85.2[b]	0.823	<0.001
Aspartic acid	85.6[a]	81.8[b]	79.4[bc]	77.1[c]	1.425	<0.001
Cystine	84.0	84.5	81.4	81.1	1.499	0.075
Glutamic acid	92.5[a]	90.6[b]	89.9[bc]	88.4[c]	0.847	0.001
Histidine	88.5[a]	87.5[ab]	86.1[bc]	84.8[c]	1.041	0.012
Isoleucine	84.8[a]	82.1[ab]	79.9[bc]	77.4[c]	1.317	<0.001
Leucine	88.1[a]	86.8[a]	85.9[ab]	84.1[b]	1.131	0.017
Lysine	89.0[a]	86.9[a]	82.1[b]	81.1[b]	1.205	<0.001
Methionine	84.7[a]	84.0[a]	79.9[b]	78.9[b]	1.895	0.014
Phenylalanine	87.4[a]	86.0[ab]	84.6[bc]	82.9[c]	1.058	0.003
Proline	90.5[a]	89.7[ab]	88.4[bc]	87.1[c]	0.802	0.003
Serine	87.4[a]	85.5[ab]	83.7[bc]	82.1[c]	1.035	<0.001
Threonine	84.6[a]	82.3[a]	78.5[b]	76.5[b]	1.336	<0.001
Tryptophan	83.8[a]	83.8[a]	76.4[b]	77.0[b]	1.986	<0.001
Tyrosine	85.0[a]	83.4[ab]	81.8[bc]	79.6[c]	1.292	0.004
Valine	85.2[a]	83.2[ab]	81.5[bc]	78.7[c]	1.323	<0.001
Glycine	86.7[a]	84.8[a]	81.4[b]	80.2[b]	1.102	1.102

[a,b,c]Means within a row with different superscripts differ significantly ($P<0.05$)

Table 22: Ileal and faecal digestibility of calcium and phosphorous in diets containing 0, 5, 10 or 15% rice hulls or barley straw, respectively, n=7.

Treatment	Bedding material inclusion (%) 0	5	10	15	SEM	P value
Calcium						
Ileal						
Rice hulls	48.0^{a}	32.5^{b}	29.1^{b}	34.6^{b}	3.25	0.004
Barley	48.0	34.6	28.4	38.0	5.74	0.144
Faecal						
Rice hulls	43.6^{a}	30.9^{b}	31.2^{b}	27.0^{b}	3.53	0.022
Barley	43.6^{ab}	41.8^{b}	31.5^{c}	50.1^{a}	3.43	0.001
Phosphorous						
Ileal						
Rice hulls	46.2	40.6	36.8	40.2	4.82	0.298
Barley	46.2	37.2	32.1	31.9	7.66	0.240
Faecal						
Rice hulls	48.8^{a}	40.5^{b}	40.7^{b}	38.1^{b}	2.89	0.018
Barley	48.0	44.9	40.4	44.2	3.28	0.182

^{a,b}Means within a row with different superscripts differ significantly (P<0.05)

The effect of bedding material type on nutrient digestibility varied with intake. At an inclusion level of 5% rice hulls diluted both faecal digestible protein and faecal digestible energy content to a greater extent than barley straw. Furthermore, at 5% inclusion the faecal digestible lysine to digestible energy ratio was lower for rice hulls (0.66 g digestible lysine:MJ DE) compared to barley straw. However, at higher bedding inclusion levels (10 and 15 %), barley straw depressed total faecal digestible protein and energy intake to a greater extent than rice hulls. Not surprisingly, this pattern was also reflected in amino acid digestibility, with both ileal and faecal amino acid digestibility generally not affected until at least 10% barley straw was consumed. In comparison, the ileal and faecal digestibility of nearly all amino acids were significantly reduced with the addition of just 5% rice hulls. Another difference with respect to the two bedding materials was their effect on site of digestion. Above 10% barley straw had a greater influence on energy digestion in the small intestine whereas rice hull consumption induced a greater depression in gross energy digestion across the whole tract.

With regards to mineral digestibility it appears that the consumption of bedding material has less effect on phosphorous digestibility than calcium digestibility. This is based on the finding that ileal phosphorous digestibility was not affected by inclusion of either bedding materials, regardless of level, and that only rice hulls affected faecal phosphorous digestibility.

In summary, results from this experiment demonstrate that consumption of as little as 5% bedding material is sufficient to significantly depress the ileal and faecal digestibility of energy, protein, amino acids and minerals and to reduce the digestible lysine to digestible energy content of a grower diet by as much as 10 to 15%. This will influence the overall efficiency of production in deep litter systems and will need to be accommodated for when formulating diets. Given that higher inclusion levels resulted in significantly greater depression of some nutrients, information is required on the amount of bedding material consumed by pigs for the correct modification of diets. Furthermore, the observation that rice hulls had different effects to barley straw on nutrient digestion means that these results are not transferable to other forms of bedding material.

Experiment 4: Validation of Remedial Diet Formulation and Feeding Strategies in Commercial Deep Litter Production Systems

Consumption of more than 5% rice hulls or 10% barley straw has been shown to significantly reduce ileal energy and amino acid digestibility (Experiment 3), whilst Experiment 2 indicated that while there was a large variation in intake between bedding types they all reduced digestibility of the diet by approximately 5%. This result suggests that if diet formulations are not adjusted to account for this difference in digestibility then we will be under-supplying both available energy and amino acids to the pigs grown in deep-litter housing systems. Based on these findings, the major aim of this experiment was to assess the ability of remedial diet formulation to counteract the dilution effect of pigs consuming bedding material in deep-litter systems through increasing the nutrient density of the diet.

Methods

Three dietary treatments were applied in a completely randomised design to determine the ability to compensate for the effects of bedding material intake within deep-litter housing systems on energy digestibility. The control treatment was a standard grower diet, 14.0 MJ DE/kg, 0.70 g AvL/MJ DE and a 5% down-specified diet (13.3 MJ DE/kg, 0.70 g AvL/MJ DE) was included to check the response of dietary treatments. The final diet was a remedial treatment that was a 5% up-specified diet (14.7 MJ DE/kg, 0.70 g AvL/MJ DE).

Three hundred and sixty female pigs (commercial genotype, 25 kg live weight) were randomly stratified according to live weight and housed in deep litter shelters with barley straw as bedding. Pigs were housed in 12 pens (30 pigs/pen) and grown from 25 kg-50 kg live weight at the Medina Research Station over a period of 6 weeks. Pigs were weighed upon entry to the pens (Week 0), Week 2, Week 4 and at the conclusion of the experiment (Week 6). Feed disappearance for each pen was also recorded at each of these time points. Bedding material was replaced every two weeks as per standard commercial practices.

Data were analysed by ANOVA (Genstat 10th edition, VSN International Ltd, Hemel Hempstead) to determine if there were significant differences in growth rate, feed consumption and feed efficiency between treatments.

Results

Changing the energy density in the diet did not have a significant effect on the growth rate of the pigs (Table 23). Numerically, feed intake was more in line with expectations with a higher level of consumption of the down-specified diet. These limited effects on growth rate and feed intake were reflected in a non-significant trend, with the pigs fed the remedial diet having a better feed conversion than the control, and those pigs fed the down-specified diet being the poorest converters.

Table 23: Growth response of pigs housed on straw to a remedial diet, where energy content was increase by 5%, with a 5% down-specified treatment included.

	Average daily gain (kg/d)	Average daily feed intake (kg/d)	Feed conversion ratio
Control	0.796	1.70	2.14
Down-specified	0.816	1.79	2.19
Remedial	0.822	1.68	2.04
SED	0.019	0.13	0.13
P value	0.383	0.665	0.506

Discussion

It is highly likely that this experiment lacked the statistical power necessary to demonstrate a significant effect of the diet changes. We have limited resource options available to us for the conduct of experiments of this nature, and in retrospect, it would have been good to repeat this experiment over time until sufficient power was available for a meaningful statistical analysis.

The numerical FCR data is in line with expectations – the down specified diet had the poorest FCR with the remedial diet the best. The magnitude of the difference is worthy of note and as a consequence, it would be irresponsible to suggest that remedial diets do not make a difference to the performance of pigs housed in deep litter systems.

Rather than undertake a further experiment with improved power to confirm this (unless an opportunity presented itself), it would be pertinent to communicate these results as they stand to commercial nutritionists and suggest it is likely a remedial diet will yield benefits when feeding pigs housed in deep litter systems.

Implications and Recommendations

This project has been very successful at achieving the stated objectives and providing the Australian pork industry with solutions for the optimal nutrition of growing pigs housed in deep litter systems. The implications of this research can be seen by examining the outcomes relative to each project objective:

Objective 1: Definition of the upper level of bedding material intake by pigs housed in commercial deep-litter systems accounting for an increase in the level of bedding material fouling over time.

Outcome 1: The amount of bedding material consumed as a percentage of the total diet consumed appears to be consistent across time and weight, with approximately 7% of the total diet of pigs housed on cereal straw being bedding material. This percentage does not change as the area of spoiled bedding material increases. This finding means that formulated diet adjustments can be made to compensate for this bedding material intake and these adjustments will be applicable regardless of pig weight and degree of bedding material spoilage.

Objective 2: Definition of the increase in *ad libitum* intake in formulated diet consumption when pigs consume a proportion of their diet as bedding material.

Outcome 2: This research has demonstrated that when pigs have access to bedding material there is no significant change in their intake of formulated feeds. It has also demonstrated that if there is an interruption in provision of formulated feed (say through a feed system blockage or delayed feed truck in a commercial system) that pigs do not increase their consumption of bedding material to compensate, however, this may be dependent on growth phase and bedding material type (in this experiment, growing pigs housed on barley straw did increase their intake of straw when provision of formulated feed was interrupted, but this difference diminished in the finisher phase). It would be reasonable to include that feed interruptions during the grower phase (when energy is the primary driver of intake) can induce an increase in consumption of palatable bedding material, but otherwise the effects are minimal.

Objective 3: Quantification of the effect of bedding material intake on the digestibility of other dietary nutrients.

Outcome 3: Results from this experiment demonstrate that consumption of as little as 5% bedding material is sufficient to significantly depress the ileal and faecal digestibility of energy, protein, amino acids and minerals and to reduce the digestible lysine to digestible energy content of a grower diet by as much as 10 to 15%. This will influence the overall efficiency of production in deep litter systems and will need to be accommodated for when formulating diets. Higher inclusion levels were shown to result in a significantly greater depression of some nutrients, however, based on outcomes from Experiment 1, it would be pertinent to formulate to a digestibility depression consistent with a 7% inclusion of bedding material. Unfortunately, the observation that rice hulls had different effects to barley straw on nutrient digestion (which is by no means surprising) means nutrient digestibility adjustments will need to be bedding material specific.

Objective 4: Development of nutritional strategies to compensate for the consequences of bedding material consumption by pigs housed in deep litter systems.

Outcome 4: The results from this research suggest that a remedial nutrition strategy is worthwhile for pigs housed on deep litter systems, demonstrate that approximately 7% of the intake is bedding material over the entire grower/finisher phase regardless of level of bedding material fouling, shows that pigs generally do not compensate for bedding material intake through higher formulated feed intake, and that at 5% bedding material intake, there is a significant depression in the digestibility of energy, amino acids and minerals. Taking all of this into account, the remedial strategy becomes very simple – formulate diets with a 5% up-specification of energy, amino acids and minerals, or incorporate appropriate enzymes to facilitate this.

Objective 5: Validation of remedial diet formulation and feeding strategies in commercial deep litter production systems and recommendations to commercial producers.

This is the only inconclusive aspect of this project, but in no way diminishes the value of the research. It appears that a lack of experimental power has prevented the demonstration of a significant benefit of the remedial formulation, but the numerical FCR data is in line with expectations – the down specified diet had the poorest FCR with the remedial diet the best. The magnitude of the difference is worthy of note and as a consequence, it would be irresponsible to suggest that remedial diets do not make a difference to the performance of pigs housed in deep litter systems.

Implications and Recommendations

Completion of this project has provided some very definitive and unique data on the consumption of bedding material by growing pigs housed in deep litter systems. The results are conclusive and provide a very simple and practical strategy for the remedial formulation of diets to compensate for bedding material intake. The structure and comprehensive nature of the project means that little additional research is required for these results to have a useful impact on the efficiency of Australian pork production. What remains is to effectively communicate these results through scientific publications, specific APL publications, industry seminars and the popular pork industry press.

Publications Arising from the Project

van Barneveld, R.J., Vandepeer, M.E., Hewitt, R.J.E., Edwards, A.C. and Choct, M. (2007) Bedding material consumption by growing pigs depresses overall diet energy digestibility**.** In 'Manipulating Pig Production XI', p 93, eds J.E. Paterson and J.A. Barker. (Australian Pig Science Association: Werribee).

van Barneveld, R.J., Vandepeer, M.E., Hewitt, R.J.E., Edwards, A.C. and Choct, M. (2007). Bedding material consumption by growing pigs alters the digestible lysine:digestible energy ratio of the diet. In 'Manipulating Pig Production XI', p 94, eds J.E. Paterson and J.A. Barker. (Australian Pig Science Association: Werribee).

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Influence of feed access and bedding material type on diet composition and diet dry matter digestibility in growing pigs. In 'Manipulating Pig Production XII', p 111, ed R.J. van Barneveld. (Australian Pig Science Association: Werribee).

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Appendix

Bedding material consumption by growing pigs depresses overall diet energy digestibility

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Deep litter housing systems are widely used by the Australian pig industry, but consumption of deep litter material (straw, rice hulls etc.) by the housed pigs makes it difficult to develop accurate diets to meet pig requirements and hence optimize the nutrition of these animals (van Barneveld *et al.*, 2003). In particular, consumption of bedding material may reduce overall nutrient and energy digestibility as well as diluting total digestible energy intake. The aim of this experiment was to define the influence of graded levels of bedding material intake on the ileal and faecal digestibility of gross energy in growing pigs.

Ileal and faecal gross energy digestibility was determined using seven male pigs (commercial genotype; 35 kg live weight) fitted with simple T-piece cannulas 15 cm anterior to the ileo-caecal valve that were fed each of seven diets in a 7x7 cross over design. A basal diet was formulated to contain 14.3 MJ digestible energy (DE) and 0.69 g available lysine:MJ DE. Celite was included in the diet as an acid-insoluble ash marker. Rice hulls and barley straw were added to the basal diet at levels of 5, 10 or 15% respectively based on upper levels of bedding material intake reported by van Barneveld et al. (2003). All diets were cold press pelleted before feeding. Following a seven-day recovery period after surgery, pigs were fed the diets for five days followed by two days of digesta and faeces collection over eight hours. Digesta was collected directly onto ice before bulking and freezing. Faeces were collected as voided, bulked and frozen. Data were subjected to an analysis of variance and means were separated by least significant difference ($P<0.05$).

Consumption of rice hulls and barley straw by growing pigs at levels of 5% had no significant effect ($P>0.05$) on the ileal digestibility of gross energy, but energy digestibility was significantly depressed at consumption levels above 10% (Table 1). A significant depression in faecal gross energy digestibility was observed for both rice hulls and barley straw at all inclusion levels. Barley straw consumption above 10% had a greater influence on energy digestion in the small intestine whereas rice hull consumption induced a greater depression in gross energy digestion across the whole tract. As well as diluting total digestible energy intake, bedding material depresses energy digestibility as consumption increases and the type of bedding material has varying influences on the site of energy digestion.

Table 1. Ileal and faecal digestibility of gross energy in diets containing 0, 5, 10 or 15% rice hulls or barley straw

	Bedding material inclusion (%)					
Treatment	**0**	**5**	**10**	**15**	**SEM**	**P-value**
Ileal						
Rice hulls	73.6^{a}	70.1^{ab}	68.8^{b}	63.76^{c}	2.13	$P<0.01$
Barley straw	73.6^{a}	70.6^{a}	63.4^{b}	57.2^{b}	3.40	$P<0.001$
Faecal						
Rice hulls	87.8^{a}	83.0^{b}	80.1^{c}	73.9^{d}	0.63	$P<0.001$
Barley straw	87.8^{a}	84.7^{b}	79.4^{c}	77.6^{d}	1.44	$P<0.001$

^{a,b,c,d}Means in a column with different superscripts differ significantly ($P<0.05$).

Supported in part by Australian Pork Limited.

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VAN BARNEVELD, R.J., DOVE, H., CADOGAN, D.J., RU, Y, EDWARDS, A.C. and CHOCT, M. (2003). In 'Manipulating Pig Production IX', p 122, ed J.E. Paterson. (Australasian Pig Science Association: Werribee).

Bedding material consumption by growing pigs alters the digestible lysine:digestible energy ratio of the diet

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The consumption of graded levels of rice hulls and barley straw by growing pigs housed in deep litter systems has the potential to reduce the ileal and faecal digestibility of gross energy significantly if consumption exceeds 5% (van Barneveld *et al.*, 2007). While increased intake may be able to compensate for a reduction in energy digestibility, this is not the case if bedding material consumption depresses the digestion of other nutrients and alters the overall digestible lysine:digestible energy ratio of the diet. The aim of this experiment was to define the influence of graded levels of bedding material intake on the ileal digestibility of lysine in growing pigs and the resulting digestible lysine: digestible energy ratio of the entire diet.

Ileal lysine digestibility was determined using seven male pigs (commercial genotype; 35 kg live weight) fitted with simple T-piece cannulas 15 cm anterior to the ileo-caecal valve that were fed each of seven diets in a 7x7 cross over design. A basal diet was formulated to contain 14.3 MJ digestible energy (DE) and 0.69 g available lysine:MJ DE. Celite was included in the diet as an acid-insoluble ash marker. Rice hulls and barley straw were added to the basal diet at levels of 5, 10 or 15% respectively, with the inclusion levels based on upper bedding material intake levels reported by van Barneveld *et al.* (2003). All diets were cold press pelleted before feeding. Following a seven-day surgery recovery period, pigs were fed the diets for five days followed by two days of digesta and faeces collection over eight hours. Digesta was collected directly onto ice before bulking and freezing. Data were subjected to an analysis of variance and means were separated by least significant difference ($P<0.05$). Ileal digestible lysine:digestible energy ratios were calculated using energy digestibility measurements reported by van Barneveld *et al.* (2007).

Consumption of rice hulls at more than 5% significantly depressed ($P<0.05$) ileal lysine digestibility whereas consumption of barley straw did not exert an influence until consumption reached 10% of the total diet (Table 1). While ileal and faecal energy digestibility is also depressed by bedding material consumption (van Barneveld *et al.*, 2007), the reduction in lysine digestibility relative to energy digestibility is sufficient to also depress the dietary digestible lysine:digestible energy ratio. This will influence the overall efficiency of production in deep litter systems and needs to be accommodated when formulating diets.

Table 1. Ileal digestibility of lysine (%) in diets containing 0, 5, 10 or 15% rice hulls or barley straw

	Bedding material inclusion (%)					
Treatment	0	5	10	15	SEM	P-value
Rice hulls	94.8a	92.5b	91.7b	88.9c	0.89	P<0.001
Barley straw	94.8a	95.1a	92.8b	93.1b	0.71	P<0.009
Ileal digestible lysine (g):digestible energy(MJ)						
Rice hulls	0.73	0.64	0.67	0.66		
Barley straw	0.73	0.68	0.57	0.62		

[abc]Means in a column with different superscripts differ significantly ($P<0.05$).

Supported in part by Australian Pork Limited.

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VAN BARNEVELD, R.J., DOVE, H., CADOGAN, D.J., RU, Y, EDWARDS, A.C. and CHOCT, M. (2003). In 'Manipulating Pig Production IX', p 122, ed J.E. Paterson. (Australasian Pig Science Association: Werribee).

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Influence of Feed Access and Bedding Material Type on Diet Composition and Diet Dry Matter Digestibility in Growing Pigs

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The Australian pig industry has rapidly adopted deep-litter housing systems for both the growing herd and to a lesser extent the breeding herd. However, the consumption of an edible bedding material (eg. straw, rice hulls) may result in reduced overall nutrient and energy digestibility of the diet. With diets formulated to meet specific pig requirements, the dilution effect of bedding material is likely to result in effects on growth and carcase quality. The aim of this experiment was to define the influence of fresh bedding material consumption on the digestibility of a formulated diet and any additional effects from diet interruption.

Forty male finisher pigs (commercial genotype, average weight 62 kg) were allocated to individual pens in a randomised complete block design, Pens were one-third solid, two-thirds clay slat (2.8 m2/pig) within a climate-controlled research facility. A frame was constructed around the solid part of the pen to facilitate the presentation of bedding material (barley straw or rice hulls) with spoiled material removed daily and replenished. Pigs were offered a finisher diet (13.5 MJ digestible energy (DE)/kg, 0.55 g available lysine/MJ DE) including 200 mg/kg of n-hexatriacontane (C-36) as an alkane marker. There were two dietary treatments: *ad libitum*, or an interrupted treatment, where feed was offered *ad libitum* on d 1 and at half the amount consumed on d 1 on the subsequent day, with this two-day cycle continuing for 21 d. Faecal samples were collected on a weekly basis and to avoid cross-contamination pens were washed and the next voided sample was collected. Alkane profiles in the bedding material, diet and faeces were determined by gas chromatography (Dove and Mayes, 2006). Diet composition and dry matter digestibility was estimated from the alkane profiles of the diets, bedding materials and faeces (*EatWhat*; Dove and Moore, 1995), after correction of faecal profiles for incomplete alkane recovery (Wilson *et al.*, 1999). Data were subjected to analysis of variance and separated by least significant differences ($P<0.05$).

Table 1. *Average daily feed intake of diet, dietary bedding material content and diet dry matter digestibility of finisher pigs offered bedding material and subjected to an ad libitum or interrupted feeding regimen.*

Bedding material	Feeding regimen	Diet average daily feed intake (kg/d)	Bedding material intake (% of diet)	Dry matter digestibility (%)
Nil	*Ad libitum*	2.80[ab]	–	84.8[a]
Barley straw	*Ad libitum*	3.00[b]	4.1[a]	80.2[b]
Barley straw	Interrupted	2.69[a]	5.2[a]	79.5[b]
Rice hulls	*Ad libitum*	2.90[ab]	14.2[b]	79.6[b]
Rice hulls	Interrupted	2.69[a]	13.3[b]	80.0[b]
P value		0.020	<0.001	<0.001

[ab]Means in a column with different superscripts differ significantly.

The intake of formulated diet under the interrupted regimen was significantly lower than those fed *ad libitum* with access to barley straw ($P=0.020$, Table 1). In general, pigs fed *ad libitum* consumed more feed when given access to bedding material. Rice hulls formed a significantly greater proportion of the diet than did barley straw ($P<0.001$), irrespective of the feeding regime, which did not influence consumption of the finisher diet. Consumption of both barley straw and rice hulls reduced diet dry matter digestibility ($P<0.001$), but the extent of the decrease was similar despite barley straw consumption being approximately one-third of rice hull consumption. These results suggest that feed interruption will not have a significant effect on the level of bedding material intake, and regardless of bedding material type or intake, diet dry matter digestibility will reduce by approximately 5%.

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