Nutritional Solutions to Environmental Challenges

PIG RESEARCH CONSORTIUM

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Contents

Preface

For over 20 years, the research collaboration between the Agri-Food and Biosciences Institute (AFBI), John Thompson and Sons and Devenish Nutrition has pioneered state of the art pig nutrition in Northern Ireland and beyond. The advances reported in this webinar and booklet are further evidence of this highly innovative and impactful relationship. Whilst the consortium have investigated many aspects of pig nutrition and management, their focus has largely been on reducing the environmental impact of pig production through dietary means.

Over the years, the Consortium have driven down phosphorus levels in diets and in doing so they have reduced the phosphorus content of pig slurry from current pig production; they have investigated the cost : benefit of non-soya protein sources which is currently of key interest as we drive towards a net zero carbon economy and over the years a key focus has been on driving down nitrogen excretion through crude protein and amino acid manipulation.

The work of the consortium has always been forward looking and the results presented here reflect that through pushing levels of crude protein to 13% successfully for finishing pigs, and in doing so significantly reducing ammonia emissions as well as odour emissions.

Over the years, funding for the vast majority of the work conducted has been gratefully received from the Department of Agriculture, Environment and Rural Affairs. As such, it is essential that the findings have an impact on the whole of Northern Ireland.

To ensure impact is realised, the Consortium not only adopt the findings into their every day practices when interacting with their customer base, they also actively disseminate their work, through forums such as this webinar and booklet.

I congratulate the Consortium on the work reported in this booklet which represents yet another major step towards sustainable pig production and I am confident that, like all the work that has gone before, the findings of this work will be adopted widely and quickly within the industry locally, nationally and internationally.

Dr Elizabeth Magowan

Director of Sustainable Agri-Food Sciences Division

Nutritional solutions to environmental challenges – The key messages

- Ammonia emissions are reduced by lowering dietary CP and this has been quantified within the Northern Ireland context. We have found that, on average, there is 10% reduction in ammonia emissions for every 1% reduction in dietary CP.

- There is a relationship between ammonia and odour emissions and reducing ammonia will ultimately reduce odour emissions.

- Nitrogen excretion in this series of trials is substantially lower than the value used in the current standard for ammonia emissions (UK Ammonia Inventory) and this work will assist in updating the Inventory.

- Lowering dietary crude protein lowers nitrogen excretion but only when diets are balanced to meet the potential of the pigs.

- Boars and gilts should be fed separately, as boars have a higher potential for lean deposition than gilts and hence retain more nitrogen.

- For optimum performance and reduced nitrogen excretion, boars should be offered diets containing 15% CP with balanced amino acids and gilts should be offered diets containing 13% CP with balanced amino acids from 60 kg to slaughter.

- There is potential that all pigs over 60 kg could be offered 13% CP with balanced amino acids but careful consideration of the effect on performance is required. The lower we try to go in dietary crude protein, the greater the precision required in raw material analysis and balancing amino acids within diets otherwise on-farm growth rates will suffer. Lower performance in terms of growth rate increases nitrogen excretion.

- Diets should not be changed during the late finishing period as changing diets (or phase feeding) is detrimental to both performance and nitrogen excretion.

- Changes in dietary fat content does not affect odour emissions from pigs or the volatile compounds that contribute to pig-house odour. However, diets low in fibre content may increase some of these odorous volatile compounds.

Targeting nutrition to reduce nitrogen excretion

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Background

Since it was formed in 1996, the aim of the Pig Research Consortium has been to provide solutions to challenges facing the pig industry and to identify opportunities to enhance the sustainability of the industry. Several programmes of work have been completed which have provided important information on nutrition and management of pigs; ranging from achieving the optimum cereal and by-product inclusion rates, optimum dietary particle size through to identifying and reducing on-farm performance variability (Ball *et al*. 2016; Ball *et al*. 2010; Magowan *et al*. 2007, Magowan *et al*. 2010abc). The Consortium has also placed strong emphasis on ensuring that the Northern Ireland industry is ahead of the game in terms of having information available to reduce the environmental impact of production. Indeed, one of the first programmes of research was on phosphorus (P) nutrition and the use of phytase (McCann *et al*. 2004) which enabled P levels of diets to be safely lowered, resulting in a 20% reduction of total P output to the environment. This work was instrumental in ensuring pig producers had accurate information to supply to the Northern Ireland Environmental Agency in support of Integrated Pollution Prevention and Control Directive (IPPC Directive 96/61/EC) licence applications and provided evidence that the pig industry had lowered P output from historic values. More recently, the Consortium has also focussed on a programme of research which aimed to reduce the overall excretion of nitrogen (N) from pig production through balanced protein nutrition and maintaining overall production performance. This programme on N excretion produced results of key significance to policy and industry and set the basis for the studies presented in the papers within this seminar booklet. To help understand the background of the work, the main outputs from the first programme of N excretion work conducted by the Pig Research Consortium are summarised below.

Summary of the first research programme on N excretion

Step one

One of the first studies by the Consortium in the area of protein nutrition was undertaken to establish the optimum energy to lysine/protein ratio in diets for growing pigs (Weatherup *et al*. 2002). It has been well established that this ratio is critical in achieving rapid lean growth in pigs. If energy is supplied in excess to protein, fat is deposited leading to a low quality carcass. On the other hand, if protein is supplied in excess, it must be deaminated and excreted, which represents an energy cost to the pig, in addition to increasing nitrogen emissions to the environment and increasing the cost of diet formulation. There are also serious negative implications if energy and protein are under supplied in a growing pig ration resulting in low rates of weight gain, poor feed efficiency and poor carcass quality hence reduced profitability. The overall objective of this early work by the Consortium was therefore to supply the correct ratio of protein and energy to drive maximum lean growth while minimising nitrogen excretion to the environment. It was found that growing pigs could be offered a lower level of dietary lysine than what was in the commercial diets at that time. The optimum ratio was 0.66 g per MJ of digestible energy which equated to 0.95% available lysine. Additionally, and of particular interest to this seminar paper, this work showed that dietary crude protein (CP) could be reduced from the then current level of 22.6% to 19.4% without any adverse effect on production performance or carcass quality. This reduction in growing pig diets resulted in 750 t/annum less N being excreted from growing pigs and provided useful information to inform decisions relating to the Nitrates Directive (Directive 91/676/EEC).

Step two

Further to this work, the Consortium initiated a series of studies on dietary crude protein and lysine levels with a view to reducing overall N excretion from pig production. It was decided to focus the work on the finishing stage as this is where the most impact could be gained in terms of the environmental benefit of reduced N excretion. One of the most effective means of reducing N output is obviously to reduce N intake through lowering dietary CP (Webb *et al*. 2014). The first trial on finishing pigs in this programme of work was conducted over the entire finishing period and investigated five levels of CP and two levels of lysine (Ball *et al*. 2013). At the time the trial was conducted, average slaughter weight in Northern Ireland was around 105 kg and thus much lower than it is currently (~123 kg). The objective of the trial was to establish the optimum level of CP and lysine for pigs offered one diet throughout the entire finishing period. To reflect commercial practice, it was decided to offer the finishing diet at transfer to the finishing accommodation when pigs were, on average 30 kg, and 10 weeks of age. The diets contained five levels of CP (14.4%, 15.5%, 16.8%, 18.2% and 19.3%) and two levels of available lysine (0.7% vs. 0.8%). Performance was poor between 10 and 13 weeks of age which indicated that all the diets were nutritionally inadequate during this early growth stage. The lower level of lysine (0.7% available lysine) was also inadequate to drive optimum growth throughout the entire finishing period. Therefore amino acid levels and balance are critical as we try to move down in levels of protein intake. In terms of dietary CP level, there was no difference in production performance and reducing CP reduced N excretion. N excretion was calculated in two ways in this study to enable an estimate for ammonia volatilisation so that N excretion figures in the Nitrates Action Programme could be revised and updated for pig production in Northern Ireland. At that time, average finisher diets contained approximately 17% CP and NAP (2011-2014) was revised accordingly using the values for N excretion from this work (Table 1). In practical terms, this equated to 382 t less organic N excreted and a lower land requirement of 2,247 hectares per annum to satisfy the 170 kg N/hectare limit. This work had significant positive implications for individual producers as less hectares are required to land spread slurry from the same number of pigs (Table 1).

TABLE 1. COMPARISON OF N EXCRETION VALUES (KG/PIG) FOR PIGS FROM “OLD” AND “REVISED” VALUES FROM RESEARCH

	“Old” values (DARD 2006)	“Revised” values (NAP 2011-2014)
Wean to 105 kg (kg N/pig)	3.4	2.4
Land required for 3000 pigs (hectares)*	60.2	42.2

Applied to 170kg N/hectare limit and 17% dietary CP

Step three

The Consortium then turned its attention to lysine and other amino acid levels to balance protein nutrition with the aim of further reducing dietary CP whilst maintaining performance throughout the finishing period (Magowan *et al*. 2016). A trial was designed to investigate the effect of lowering CP from 17% balancing amino acids down to threonine, to 15% but balancing down to several potential limiting amino acids beyond threonine in the "ideal protein" ratio. The concept of the "ideal protein" ratio is to supply dietary essential amino acids in similar ratios to that of the pig muscle (ARC 1981) and as lysine is the first limiting amino acid in pig diets, ideal protein is set in ratio to lysine with other amino acids being supplied in balance to lysine. A number of essential amino acids are available in synthetic form and can be included in the diet formulation. However, not all are available and increased inclusion of synthetic amino acids increases the cost of diet production. Hence, it is important to establish the appropriate ratio of each amino acid relative to lysine to reduce the overall use of synthetic amino acids while still reducing dietary CP to lower N excretion. Six diets were formulated; 1) 17% CP with ideal protein down to threonine, 2) 15% CP with ideal protein down to threonine, 3) 15% CP with ideal protein down to tryptophan, 4) 15% CP with ideal protein down to valine, 5) 15% CP with ideal protein down to valine plus DeviGain, 6) 15% CP with a 10% lower level of lysine and ideal protein down to tryptophan plus DeviGain. DeviGain supplies amino acids bound on a sugar matrix. The diets were offered to finishing pigs from 12 weeks of age until finish at 22 weeks in mixed pens. In the very early finishing period, there was a benefit to formulating down to tryptophan and valine but throughout the overall finishing period, there was no significant difference in the performance of pigs (Table 2). However, numerically, formulating down to tryptophan improved FCR and has produced commercial benefits. It was concluded that finishing pig diets could be reduced to 15% CP provided amino acids were provided in a balanced ratio with no drop in performance. This reduction in dietary CP equated to a 22% reduction in N excretion which is of considerable importance in the context of the environmental impact of production. Also of significance was that through the use of DeviGain, the amount of synthetic amino acids required to maintain performance could be lowered by 10% reducing diet costs by approximately £7.30/t.

TABLE 2. THE EFFECT OF LOWERING CP WITH AMINO ACID SUPPLEMENTATION ON FINISHING PIG PERFORMANCE AND N EXCRETION

	17% CP	15% CP with ideal protein*	SEM	P
Start weight (kg)	39.5	40.3	0.49	NS
Finish weight (kg)	111.1	112.3	1.27	NS
Daily feed intake (g/d)	2207	2235	69.2	NS
Average daily gain (g/d)	903	912	20.8	NS
Feed conversion ratio	2.45	2.45	0.050	NS
N excretion (g/d)	38.7	30.3	1.48	<0.001

*supplied by synthetic amino acids and DeviGain.

Key findings and outcomes

The findings from the trials described above are summarised below and led the Consortium into the next programme of work which will be specifically detailed within this seminar booklet in separate papers.

- N excretion can be reduced by lowering crude protein intake but it is important to ensure that this is done without any detrimental impact on production performance.

- Getting the total amino acid balance of the diet correct is critical to ensuring that animal performance is maintained.

- The NAP programme was revised and updated to reflect the reductions in N excretions as a result of the research.

- As a result of the trials outlined above, a significant proportion of producers in Northern Ireland have reduced dietary CP in finishing pig diets from historic levels of approximately 18% down to 15% (with a more balanced amino acid supply) leading to substantial reduction in N excretion.

Key questions which have been answered by the next programme of research on N excretion

- Can dietary CP levels be reduced below 15% bearing in mind the need for balanced amino acid supply?

- The work summarised above was conducted on mixed groups of pigs and the question remained if boars, which require a higher amino acid supply, would respond differently than gilts when offered lower levels of CP and lysine.

- Slaughter weight has increased significantly in recent years and while many producers are offering the one finishing diet throughout the finishing period, is there room to lower CP in the later finishing period and thus reduce N excretion?

- Reducing N excretion will also reduce ammonia excretion and potentially odour emissions but this has not been quantified in the studies thus far. Quantifying the effect of reducing dietary CP on ammonia and odour production is of paramount importance to enable producers to continue to operate within the confines of environmental legislation. Can the effect of reducing dietary CP on ammonia excretion be quantified within the Northern Ireland context?

References

Agricultural Research Council (ARC). (1981). The nutrient requirements of pigs. Commonwealth Agricultural Bureau, Slough, UK.

Ball, M.E.E., Magowan, E., McCracken, K.J., Beattie, V.E., Bradford, R., Gordon, F.J., Robinson, M.J., Smyth, S. and Henry, W. (2013). The effect of level of crude protein and available lysine on finishing pig performance, nitrogen balance and nutrient digestibility. *Asian-Australasian Journal of Animal Science*, 26: 564-572.

Ball, M.E., Magowan, E., McCracken, K.J., Beattie, V.E., Bradford, R., Thompson, A., Gordon, F.J. (2016). An investigation into the effect of dietary particle size and pelleting of diets for finishing pigs. *Livestock Science*, 173: 48-54.

Ball, M. E. E., Magowan, E., Beattie, V. E., McCracken, K. J., Henry, W., Smyth, S., Bradford, R., Gordon, F. J., Mayne, C. S. (2010). The effect of dietary energy source on performance and nutrient digestibility in growing pigs. *Journal of Animal and Feed Sciences*, 19(3): 408-417.

Magowan, E., Ball, M. E. E., Beattie, V. E., McCracken, K. J., Bradford, R., Scott, M. (2010a). The performance response of pigs of different wean weights to high or low input dietary regimes between weaning and 20 weeks of age. *Livestock Science*, 136: 232-239.

Magowan, E., McCann, M.E.E., Beattie, V.E., McCracken, K.J., Henry, W., Smyth, S., Bradford, R., Gordon, F.J., and Mayne, C.S. (2007). Investigation of growth rate variation between commercial pig herds. *Animal*, 1: 1219-1226

Magowan, E., Ball, M. E. E., McCracken, K. J., Beattie, V. E., Bradford, R., Robinson, M. J., Gordon, F. J., Scott, M., Mayne, C. S. (2010b). Effect of dietary regime and group structure on pig performance and the variation in weight and growth rate from weaning to 20 weeks of age. *Livestock Science*, 136: 216-224.

Magowan, E., McCann, M.E.E., Beattie, V. E., McCracken, K. J., Henry, W., Smyth, S., Bradford, R., Gordon, F. J., Mayne, C. S. (2010c). The effect of the method of dietary oil addition to pelleted diets on performance and nutrient digestibility in finishing pigs. *Animal Feed Science and Technology*, 156: 89-96.

Magowan, E., McCracken, K., Smyth, S., Gordon, F., Kennan, J., Beattie, V. (2016). Impact of amino acid formulation strategy on finishing pig performance. 2016 67th EAAP annual meeting, Belfast, 2016 August: Abstract.

McCann, M.E.E., McCracken, K. J., Beattie, V. E., Magowan, E., Smyth, S., Bradford, R., Henry, W. (2004). Investigations into phosphorus requirements of growing/finishing pigs and the use of phytase. Proceedings of a seminar held at the Agricultural Research Institute of Northern Ireland, Occasional Publication No. 33: 51-64.

Webb, J., Broomfield, M., Jones, S., Donovan, B. (2014). Ammonia and odour emissions from UK pig farms and nitrogen leaching from outdoor pig production. A review. *Science of the Total Environment*, 470-471: 865-875.

Weatherup, R.N., Beattie, V.E., McCracken, K.J., Henry, R.W., McIlroy, S.G. and Smyth, S. (2002). The effects of energy and lysine concentrations in grower diets for pigs on performance from 8 to 12 weeks of age. *Irish Journal of Agricultural and Food Research*, 41: 95–104.

Lowering dietary crude protein in finishing pig diets – the effect on ammonia, odour and slurry production

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Background

Ammonia gas is an environmental pollutant and has resulted in a detrimental effect on areas of special scientific interest with the loss of biodiversity. This loss of biodiversity not only negatively changes the natural environment but also reduces carbon sequestration ability, which has wider negative implications in terms of greenhouse gas emissions. Furthermore, ammonia is also a significant source of nitrous dioxide, a potent greenhouse gas, which causes environmental damage at both a local and global level (Magowan *et al*. 2015). Ammonia from pigs is primarily produced through the mixing of urine and faeces. The nitrogen (N) in the urine, in the form of urea, is converted to ammonium through the action of the enzyme urease which is present in the faeces. When excreted, the process of ammonium production begins and depending on conditions (e.g. temperature and pH), the ammonium is dissociated to ammonia which is then volatilised as ammonia gas (Phillippe *et al*. 2011). It is this ammonia gas that can cause health and welfare problems for humans and pigs (Banhazi *et al*. 2008), as it affects air quality and ultimately is deposited on land causing acidification, the loss of biodiversity and environmental problems. Ammonia production can be reduced by reducing urinary N excretion and by management post excretion to reduce dissociation from ammonium to ammonia. The focus of the work presented in this paper was to reduce overall N excretion through reduced N intake.

While pig production only contributes 8% of ammonia from Northern Ireland agriculture (Gilliland *et al*. 2017), pig units close to sensitive areas and other large livestock enterprises are under particular scrutiny. As well as this, Northern Ireland has a particular ammonia problem due to its high agricultural output, therefore a reduction in ammonia output is key for industry survival in terms of meeting environmental legislation (Gothenburg Protocol (1999) and Habitats Directive (1992)). In addition, odour emissions from pig units are problematic, which can cause issues with neighbours, if in excess, and also hinder business expansion. There are a number of ways that ammonia and odour production can be reduced, with most focus on altering the diet. A reduction in the level of dietary crude protein (CP) will result in less nitrogen excreted, and a reduced potential for ammonia creation, provided CP and digestible amino acids are adequately supplied and the diet is formulated to ensure that production performance is maintained (Sajeev *et al*. 2017). It has been estimated that a 1% unit reduction in dietary CP content can lead to an 8-10% reduction in ammonia production (Magowan *et al*. 2015). Some Northern Ireland producers of finishing pigs have substantially reduced dietary CP content from traditional levels but the effect on ammonia output has not been quantified. The Pig Research Consortium identified the need to validate the relationship between dietary CP content and ammonia production in specially designed trials.

The relationship between dietary CP content and odour production is not clear (Morazán *et al*. 2015) but there is evidence to suggest that modifying the dietary CP content and other dietary ingredients affects the microbial profile within the gastrointestinal tract to divert N from urine to faeces which reduces the production of ammonia and odorous compounds (Aarnink and Verstegen, 2007). Furthermore, the effect of lowering dietary CP on slurry production has not been well established, although research would indicate that water intake is reduced as a result of lowering CP (Mroz *et al*. 1995) reducing overall slurry production.

The objective of this study was to investigate the effect of offering finishing pigs high (traditional), medium or low dietary CP on ammonia and odour emissions and subsequent slurry production.

Materials and methods

Thirty boar pigs (Danish Duroc) were individually housed in batches of six, from 10 weeks of age (30 ± 3.0 kg) and offered standard pre-trial diets (diet A: 18.5% CP, 15.0 MJ/kg digestible energy (DE) between 10 weeks of age and 45 ± 3.0 kg, followed by diet B: 16.5% CP and 14.3 MJ/kg DE to 75 ± 1.5 kg). Pigs were then assigned to one of three treatment diets; 1) 18.0% CP, 1.10% lysine (High CP), 2) 150% CP, 1.13% lysine (Medium CP), and 3) 13% CP, 0.90% lysine (Low CP). Diets were formulated by John Thompson and Sons to the same DE (14.0 MJ/kg) and balanced for ideal protein. A total collection of faeces over a four-day period was conducted to determine total tract digestibility of dry matter, N, oil, ash and fibre and to determine the digestible energy content of the diet. After three weeks on the experimental diets, six pigs were moved on a weekly basis to individual calorimetry respiration chambers to measure ammonia and odour emissions. After ~24 h in the chambers, the analysers began recording ammonia production for a total of ~73 h. At ~28 h of recording, odour concentration was measured using dynamic olfactometry (BSEN13725:2003). At the end of the recording period, the pigs were removed from the chamber, weighed and their feed disappearance recorded to calculate dry matter intake (DMI). The slurry in each chamber was collected, weighed, stored for five months and analysed for volatile odorous compounds. Data were analysed using a general analysis of variance (ANOVA) in Genstat 16.0, with DMI used as a co-variate.

Results and discussion

Diets were analysed to contain 18.4%, 14.8% and 13.2% CP but were formulated to 18%, 15% and 12% respectively. It is interesting to note that analysed values for the 18% and 15% CP were very similar to the formulated values but the 12% formulated diet contained slightly higher CP on analysis. The diets contained common dietary ingredients used across finishing diets in Northern Ireland and the major components are shown in Table 1. Wheat, barley and maize were used as the cereal component and maize DDGS, wheat pollard and rapeseed meal comprised the by-product component. Soyabean meal inclusion decreased to reduce the dietary CP content and in the 13% CP diet, there was a 0% inclusion of soyabean meal. Formulating and producing diets with lower levels of soyabean meal reduces the reliance on imported soyabean meal and reduces the carbon footprint of production. The higher level of CP (18.4%) is a more traditional level with the majority of the industry having moved to lower CP levels in the finishing stage. The lower level of 13.2% is not typical of finishing diets but was included in this work to establish the potential to reduce N excretion with a view to deciding “how low we can go”.

TABLE 1. MAIN DIETARY INGREDIENTS OF DIETARY TREATMENTS WITH FORMULATED AND ANALYSED CONTENTS (%)

	18% CP	15% CP	13% CP
Main ingredients (%)			
Cereal	65	76	84
By-products	16	10	10
Soyabean meal	16	8	0
Formulated content (%)			
CP	18.2	15.0	12.1
Lysine	1.1	1.1	0.9
Lys:CP ratio	0.06	0.07	0.07
Analysed content (%)			
CP	18.4	14.8	13.2
Lysine*	0.98	0.92	0.88
Lys:CP ratio	0.05	0.06	0.07

*Includes 0.1% from DeviGain

This study focused primarily on the effect on emissions of reducing dietary CP. The overall effect, including implications of reducting dietary CP on performance will be discussed further in the following papers (Beattie *et al*. 2020; Ball *et al*. 2020). However, under the conditions of this study, where pigs were housed individually and received optimum husbandry and management, there was no significant effect of lowering CP on overall performance (Table 2). While it was important to measure individual performance in this study to prepare pigs for the calorimetry chambers and to enable calculations to be conducted for emission values, it is not applicable to transfer these performance results across to the commercial setting which is why further studies were conducted to fully establish and validate the effect on performance. As maintenance of performance is critical to realising benefits from lower CP diets, the potential reductions in emissions with lowering dietary CP must be viewed within that context.

TABLE 2. THE EFFECT OF LOWERING DIETARY CP ON INDIVIDUAL PIG PERFORMANCE

	18% CP	15% CP	13% CP	SEM	P
Intake (kg/d)	3.40	3.49	3.34	0.107	NS
ADG (kg/d)	1.28	1.37	1.35	0.040	NS
FCR (kg/kg)	2.67	2.57	2.50	0.113	NS
End weight (kg)	110.4	112.9	112.1	1.87	NS

The effect of dietary treatment on nitrogen intake, water intake, ammonia, odour and slurry output are shown in Table 3. Reducing the dietary CP obviously resulted in a significant reduction in N intake corresponding to the level of CP in the diet. The reduction of CP in the diet from 18 to 15% resulted in a 12% reduction in ammonia emissions, and from 18 to 13% CP, lead to a 48% reduction (P = 0.045). This magnitude of reduction is in keeping with previously published work conducted in countries with similar environmental conditions and production systems as Northern Ireland. For example, Kay (1997) reported a reduction of around 10% reduction in ammonia emission for every 1% unit decrease in dietary CP. Additionally, Webb *et al*. (2014) summarised six studies and concluded that ammonia emissions decreased by 8% for every 1% unit decrease in dietary CP. In the current study, considering the reduction in ammonia emissions by offering 13% cf. 18%, we have found that ammonia emissions reduced by 10% for every 1% decrease in dietary CP. This is a critical finding as it not only validates the relationship between dietary CP reductions and ammonia emissions but it also provides evidence that Northern Ireland pig producers have reduced ammonia emissions since the move away from the traditional higher levels (18%) of CP in finishing diets.

Digestibility of DM, CP, oil, fibre and energy was not affected by dietary treatment (Table 3). The values are similar to other publications on the digestibility of pig diets (e.g. Portejoie *et al*. 2004) and support the non-significant effect on performance due to dietary CP level.

TABLE 3. THE EFFECT OF REDUCING DIETARY CRUDE PROTEIN ON N INTAKE, AMMONIA OUTPUT AND NUTRIENT DIGESTIBILITY

	18% CP	15% CP	13% CP	SEM	P
Nitrogen intake (g)	325[b]	270[a,b]	238[a]	2.2	<0.001
Ammonia (mg/h)	430[b]	378[a,b]	223a	58.3	0.045
Dry matter digestibility (%)	85.8	86.5	87.0	1.20	NS
Nitrogen digestibility (%)	83.0	81.6	81.8	1.810	NS
Oil digestibility (%)	73.8	69.5	73.4	2.58	NS
Fibre digestibility (%)	50.5	43.8	44.2	5.84	NS
Energy digestibility (%)	85.1	85.6	86.7	1.29	NS

[a,b] superscripts indicate significance. Means without identical superscripts are significantly different (P<0.05)

Lowering CP to either 15 or 13% reduced water usage (P = 0.013) and slurry excreted per day (P < 0.001, Table 4). The reduction in water usage equated to 25% less water usage and 38% less slurry produced per day. The higher level of water usage on the 18% CP diet indicates that CP was supplied in excess and that the pig had to deaminate the protein and excrete the excess as urea in the urine (a process which requires energy and water (NRC 1998)). The non-significant difference in water usage of pigs offered either 15 or 13% dietary CP would suggest that the 15% CP diet was not over supplying CP. Reducing water intake directly reduces urine and therefore slurry output and the observed reduction of 38% less slurry is in keeping with the magnitude of reductions reported by others. For example, Portejoie *et al.* (2004) reported a 38% reduction in slurry output when dietary CP was reduced from 20 to 12%. Reducing overall slurry output, will have obvious practical benefits for pig producers and the reduction observed in this study is equivalent to 58 tankers (1300 gallon tanker) for a 2000 finisher place house.

TABLE 4. THE EFFECT OF REDUCING DIETARY CRUDE PROTEIN ON WATER USAGE, SLURRY OUTPUT AND SLURRY DRY MATTER

	18% CP	15% CP	13% CP	SEM	P
Water usage (L/day)	6.4[b]	5.1[a]	4.8[a]	0.39	0.013
Slurry output (L/day)	3.4[b]	2.1[a]	2.1[a]	0.21	<0.001
Slurry DM (%)	8.1[a]	9.1[ab]	12.5[b]	1.10	0.025

[a,b] superscripts indicate significance. Means without identical superscripts are significantly different (P<0.05)

While there was no significant effect of reducing dietary CP on odour emissions or hydrogen sulphide emissions, there were numerical differences which may be important in the commercial setting (Table 5). The odour emissions measurement used in this study is a standardised method to measure odour using the human sense of smell. A sample of the odour was taken from the calorimetry chamber and then presented to trained panel members who identified the level of dilution required in order for its minimum detection threshold to be reached. This is expressed in odour units per m^3 and in this study, subsequently converted to odour units per sec (OUe/sec) using the air flow rate measured in the chambers. Thus, the lower the value, the less dilution required to reach minimum detection and therefore the lower odour. The average value (1.94 OUe/sec) obtained for odour emissions in this study is substantially lower than other published values. For example, Hove *et al*. (2016) reported average values of 28.7 OUe/sec while Webb *et al*. (2014) suggested a range of 10-20 OUe/sec for finishing pigs. The lower values obtained in this study can be explained by the fact that odour emission measurements were taken from the chambers when pigs had only been *in situ* for around 28 hrs. The chambers were cleaned before entry and the slurry pits were also clean and dry. Therefore, there was little time for odour to build up within the chamber and relatively little slurry for odour to be emitted from. However, as all pigs offered the different dietary treatments were treated identically, the comparative differences between odour arising from pigs offered the dietary CP levels are valid. There are hundreds of different compounds and chemicals that contribute to pig odour and odour emissions from pig production. Magowan *et al*. (2015) listed 28 of the key problem chemicals and ranked them in order of odour activity value (Parker *et al*. 2012). The five most potent compounds were reported to be hydrogen sulphide, p-cresol, dimethylsulphide, ammonia and butanoic acid. Reducing dietary CP should in theory have caused a reduction in odour production as these and other compounds are produced from the microbial breakdown of N and other nutrients in the slurry (Bindelle *et al*. 2008). However, the fact that there was little time for slurry to build-up and for decomposition to occur, may have masked the potential impact of reducing dietary CP on odour concentration.

For this reason, the slurry was stored for five months and then analysed for volatile odorous compounds. There was no significant effect of dietary CP on the majority of the compounds which is in contrast to Sungback *et al*. (2015) who reported a reduction in odour compounds as dietary CP was decreased (Table 6). However, skatole levels were significantly higher (P<0.01) in the slurry from pigs offered the 13% CP diet. This skatole result is difficult to explain as Sungback *et al*. (2015) reported that lowering dietary CP caused a shift in the microbial profile within the gut and resulted in less skatole producing bacteria. This apparent adverse effect on skatole production in slurry from pigs offered lower CP diets warrants further investigation before a firm conclusion can be drawn.

TABLE 5. THE EFFECT OF REDUCING DIETARY CRUDE PROTEIN ON ODOUR AND HYDROGEN SULPHIDE EMISSIONS

	18% CP	15% CP	13% CP	SEM	P
Odour emission (OuE/Sec)	2.18	1.87	1.76	0.32	NS
Hydrogen Sulphide (ppm)	2.25	1.61	1.32	0.34	NS

TABLE 6. THE EFFECT OF REDUCING DIETARY CRUDE PROTEIN ON VOLATILE ODOROUS COMPOUNDS FROM STORED SLURRY

	18% CP	15% CP	13% CP	SED	P
Acetic acid (ng)	5.0	0.9	5.2	6.07	NS
1H-Pyrrole, 3-methyl- (ng)	7.6	6.3	8.0	2.85	NS
Disulfide, dimethyl (ng)	321	289	314	96.9	NS
Toluene(ng)	2.1	2.4	2.0	0.18	NS
4-Octene, (E)- (ng)	7.1	7.5	2.6	2.34	NS
2-Heptanone (ng)	37	25	30	11.0	NS
Nonane (ng)	0.7	0.8	1.4	0.99	NS
Butyrolactone (ng)	1.2	1.1	1.0	0.89	NS
Benzaldehyde (ng)	0.7	1.2	1.5	0.74	NS
Dimethyl trisulfide (ng)	133	112	115	31.5	NS
Phenol (ng)	236	220	201	29.3	NS
2-Octanone (ng)	3.8	2.4	2.4	1.44	NS
2-Nonanone (ng)	13.7	8.5	12.8	3.94	NS
2-Decanone (ng)	2.8	1.9	1.5	0.93	NS
Indole (ng)	84	87	89	10.3	NS
Skatole (ng)	145[a]	166[a]	232[b]	21.4	0.005

[a,b] superscripts indicate significance. Means without identical superscripts are significantly different (P<0.05)

Despite some studies listing ammonia as a potent, odorous compound, the relationship between ammonia and odour production has not been well established. In the current study when the relationship between ammonia emission and odour emission was statistically analysed, there was a positive relationship between odour and ammonia (Linear: $R^2 = 0.25$, $P = 0.005$). As can be seen from Figure 1, there is a relationship, although weak, which would suggest that reducing ammonia may also reduce odour emissions.

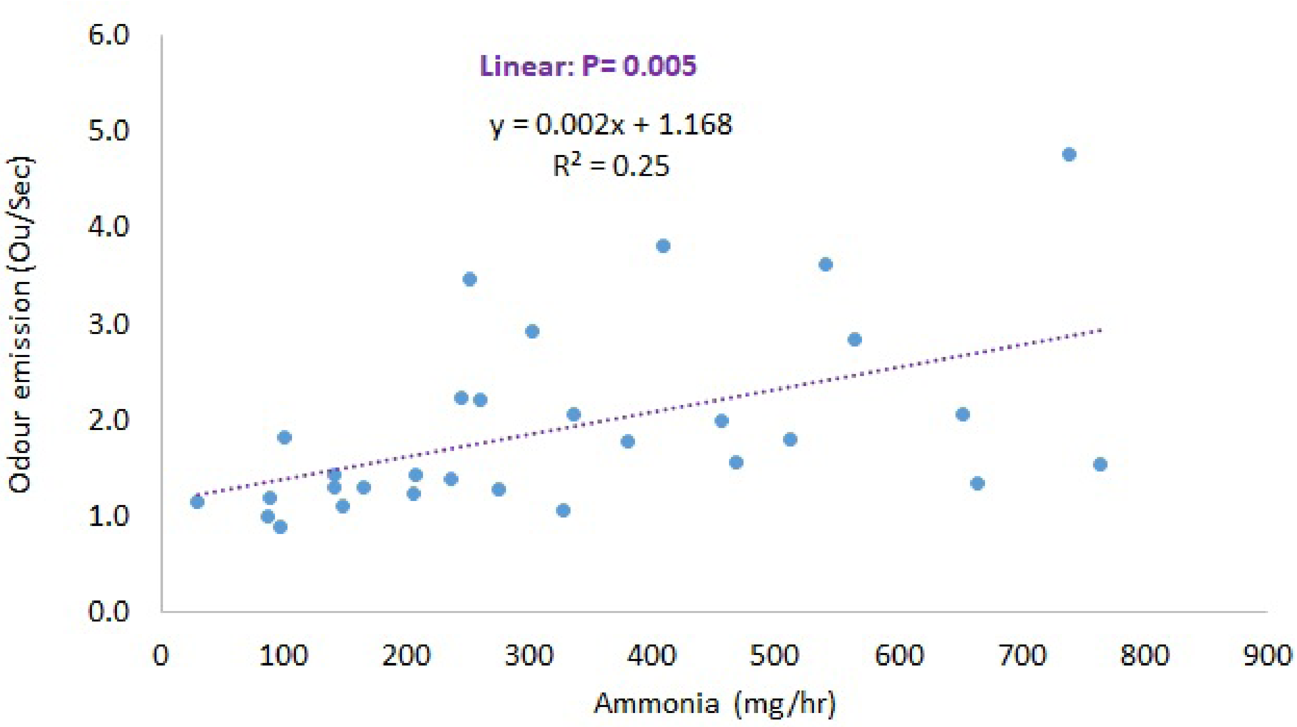

FIGURE 1. THE RELATIONSHIP BETWEEN AMMONIA EMISSIONS AND ODOUR EMISSIONS

Summary

- Overall, ammonia emissions were reduced by reducing dietary CP, and on average, equates to a 10% reduction for a 1% reduction in dietary CP.
- This work validated the relationship between dietary CP and ammonia emissions within a Northern Ireland context and provides evidence that pig producers have lowered ammonia emissions.
- Lower dietary CP reduced water usage and subsequently lowered slurry output.
- The numerical differences between odour emissions and hydrogen sulphide production suggest that lowering dietary CP may reduce odour.
- There is a statistically significant relationship between ammonia and odour.
- It is important to consider production performance when lowering dietary CP even when the dietary reductions are balanced to supply essential amino acids.
- Lower dietary CP reduces the reliance on imported soyabean meal, thus reducing the carbon footprint of production.

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References

Aarnink, A.J.A., Verstegen, M.W.A. (2007). Nutrition, key factor to reduce environmental load from pig production. *Livestock Science*, 109:194–203.

Bindelle J., Leterme P., Budgen A. (2008). Nutritional and environmental consequences of dietary fibre in pig nutrition: a review. *Biotechnology, Agronomy, Society and Environment*, 12:69-80.

Gilliland J. (2017). Making Ammonia Visible, An Annex to "*Delivering Our Future, Valuing Our Soils: A Sustainable Agricultural Land Management Strategy for Northern Ireland*", Produced by the Expert Working Group on Sustainable Agricultural Land Management for N. Ireland, December, 2017.

Gottenburg Protocol (1999). Economic Commission for Europe Executive Body for the Convention on Long-range Transboundary Air Pollution. Guidance document on preventing and abating ammonia emissions from agricultural sources. ECE/EB.AIR/113/Add.1, decision 2012/11. https://www.unece.org/fileadmin/DAM/env/documents/2012/EB/ECE_EB.AIR_120_ENG.pdf.

Habitats Directive (1992). Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043.

Hove, N.C., Van Langenhove, H., Van Weyenberg, S. and Demeyer, P., 2016. Comparative odour measurements according to EN 13725 using pig house odour and n-butanol reference gas. *Biosystems Engineering*, 143:119-127.

Kay, R.M. (1997). Ammonia emission from pigs buildings and characteristics of slurry produced by pigs offered low crude protein diets. *In Proceeding International Symposium Ammonia and Odour Control from Animal Production Facilities, Vinkelord, The Netherlands, 1997*, 245-252.

Morazán, H., Alvarez-Rodriguez, J., Seradj, A.R., Balcells, J. and Babot, D. (2015). Trade-offs among growth performance, nutrient digestion and carcass traits when feeding low protein and/or high neutral-detergent fiber diets to growing-finishing pigs. *Animal Feed Science and Technology*, 207:168-180.

Mroz, Z., Jongbloed, A.W., Lenis, N.P. and Vreman, K. (1995). Water in pig nutrition: physiology, allowances and environmental implications. *Nutrition Research Reviews*, 8(1):137-164.

National Research Council. (1974). *Nutrients and Toxic Substances in Water for Livestock and Poultry. National Academy Press*, Washington, DC.

National Research Council. (1998). Nutrient Requirements of Swine (10th edition). *National Academy Press*, Washington, DC.

Parker, D.B., Koziel, J.A., Cai, L., Jacobson, L.D., Akdeniz, N., Bereznicki, S.D., Lim, T.T., Caraway, E.A., Zhang, S., Hoff, S.J. and Heber, A.J., 2012. Odor and odorous chemical emissions from animal buildings: Part 6. Odor activity value. *Transactions of the ASABE*, 55(6):2357-2368.

Philippe, F.X., Cabaraux, J.F. and Nicks, B. (2011). Ammonia emissions from pig houses: Influencing factors and mitigation techniques. *Agriculture Ecosystems & Environment*, 141(3-4):245-260.

Portejoie, S., Dourmad, J.Y., Martinez, J. and Lebreton, Y. (2004). Effect of lowering dietary crude protein on nitrogen excretion, manure composition and ammonia emission from fattening pigs. *Livestock Production Science*, 91(1-2):45-55.

Sajeev, E.P.M., Amon, B., Ammon, C., Zollitsch, W. and Winiwarter, W. (2018). Evaluating the potential of dietary crude protein manipulation in reducing ammonia emissions from cattle and pig manure: A meta-analysis. *Nutrient cycling in agroecosystems*, 110(1):161-175.

Sungback, C., Okhwa, H. and Sungkwon, P. (2015). Effect of Dietary Protein Levels on Composition of Odorous Compounds and Bacterial Ecology in Pig Manure. *Asian Australasian Journal of Animal Science*, 28: 1362-1370.

Thalin, P. A., and M. C. Brumm, M. C. (1991). *Water: The forgotten nutrient*. Swine Nutrition, Stoneham, MA, USA, 315-324.

Webb, J., Broomfield, M., Jones, S. and Donovan, B. (2014). Ammonia and odour emissions from UK pig farms and nitrogen leaching from outdoor pig production. A review. *Science of the total environment*, 470:865-875.

Low protein diets in late finishing: performance and excretion

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Background

The average carcass weight of pigs slaughtered in Northern Ireland (NI) so far in 2020 is 94.0 kg (PIGIS). This has risen by approximately 25 kg in the last 20 years and is now in line with other European countries. For example, the average carcass weight in Denmark is 87.4 kg, Germany 94.5 kg and the two main pig producing eastern European countries, Hungary and Poland, 92.5 kg. The average carcass weight in the UK is 84.9 kg (DEFRA, 2019) and this includes NI weights (NI pigs are approx. 10-15% of UK kill) suggesting that carcass weight in GB is less than 84.9 kg. Recommendations regarding nutrition of pigs with liveweights greater than 100 kg are predominately based on castrates as the majority of male pigs on mainland Europe are castrated. The potential to deposit lean tissue in castrates is around 70% that of entire males hence the nutritional requirements are very different (Whittemore, 1998; Weatherup *et al*. 1998).

In young pigs, the response of protein retention to feed intake is linear up to maximum appetite, while in slightly older animals, protein retention reaches a plateau at higher levels of feed intake. Gompertz assumptions indicate that maximum limits to daily protein retention are rather constant over a wide range of liveweights covering 10-50% of mature weight, approximately 30-140 kg liveweight for pigs. During the linear phase for lean growth, fatty tissue growth will be restrained to a minimum level on the assumption that under normal growth the animal prefers to target for lean whilst maintaining some minimal level of fat in normal liveweight gains. In entire males the ratio of fat to lean can be less than 0.5 fat to 4 of lean. However, in castrates the ratio can be as much as 2 of fat to 4 of lean.

Breeding companies recommend 13-15% less lysine for castrates and 10% less lysine for gilts compared to entire males at liveweights over 100 kg. In practice boars and gilts are housed together hence, any potential to reduce protein and amino acid concentrations for gilts may be detrimental for boars. The aim of this work was to identify the optimum protein and amino acid dietary concentration for boars and gilts from 60 kg liveweight to 140 kg liveweight.

Materials and methods

Trial at AFBI, Hillsborough

Effect of dietary crude protein level and gender on performance and nitrogen (N) excretion of heavy slaughter weight pigs.

In this study, 144 pigs were used in a 2 x 3 factorial design with two sexes (boars and gilts) offered three different feeding regimes.

The feeding regimes were:

(1) 13:13 13% CP, 0.9% lysine diet offered from 60-140 kg

(2) 15:15 15% CP, 1.125% lysine diet offered from 60-140 kg

(3) 15:13 15% CP, 1.125% lysine diet offered from 60-100 kg and 13% CP, 0.9% lysine diet offered from 100-140 kg.

Pigs were reared under normal commercial conditions until 10 weeks of age. At 10 weeks of age pigs were allocated to treatment in groups of 12. This was carried out across two batches of pigs hence 24 pigs per treatment. Pigs were offered a commercial grower diet in pellet form (CP 18.5%, lysine 1.3%) until 12 weeks of age. At 12 weeks of age they were offered a pre-finisher diet (CP 16.5%, lysine 1.25%) until the average weight of each group was 60 kg. Each pen was equipped with an MLP FIRE feeder which recorded individual feed intake and bodyweight at each visit. Feed intake and bodyweight data from the feeding stations were used to calculate average daily feed intake and linear-regressed daily live weight gain (LWG) (according to MacNeil and Kemp, 2014) for each individual pig. This was then used to calculate feed conversion ratio (FCR) for each pig. Pigs were weighed manually at six time points during the trial to validate the weights recorded by the feeders. Pigs were slaughtered when the pen weight averaged 140 kg.

Data was analysed as a 2x3 factorial via REML with start weight (when average pen weight was approximately 60 kg) as a co-variate.

Trial at Commercial Unit

Effect of dietary crude protein level on performance and nitrogen excretion of heavy slaughter weight pigs.

In this study, 441 pigs were used across three different feeding regimes. The feeding regimes were:

(1) 13:13 13% CP, 0.9% lysine diet offered from 60-120 kg

(2) 15:15 15% CP, 1.125% lysine diet offered from 60-120 kg

(3) 15:13 15% CP, 1.125% lysine diet offered from 60-100 kg and 13% CP, 0.9% lysine diet offered from 100-120 kg.

Pigs were reared under normal commercial conditions until 13 weeks of age. At 13 weeks of age pigs were allocated to treatment in groups of 21. Pigs were offered a commercial grower diet in pellet form (CP 17.5%, lysine 1.2%) until 13 weeks of age. At 13 weeks of age they were offered a pre-finisher diet (CP 16.5%, lysine 1.25%) until the average weight of each group was 60 kg. Pigs were weighed weekly to ascertain when the pen weight averaged 60 kg. All deaths and removals were weighed off trial and the date recorded. Pigs were weighed in their pen group every two weeks during the trial. As pigs approached 100 kg, they were weighed weekly to get the change of diet as close to 100 kg as possible. Weekly weighing continued until pigs reached slaughter weight at 120 kg. Dead weights and P^2 were collected at the factory. Results were analysed using ANOVA.

Diets

TABLE 1. DIETS AND ANALYSIS OF DIETS USED IN BOTH THE AFBI TRIAL AND COMMERCIAL TRIAL

	Diet			
	13% CP 0.9% lysine		15% CP 1.125% lysine	
Barley	25.0		27.5	
Wheat	44.7		34.4	
Maize	15.5		15.5	
Pollard	5.0		5.0	
Rapeseed extract	5.0		5.0	
Hipro soya	0		8.0	
Soya oil	1.2		1.0	
Limestone	0.94		0.91	
Mono DCP	0.35		0.28	
Salt	0.33		0.33	
Lysine	0.47		0.50	
Methionine	0.03		0.1	
Threonine	0.14		0.17	
Tryptophan	0.02		0.03	
Mins & vits	0.3		0.3	
DeviGain*	1.0		1.0	
	13% CP		15% CP	
	Formulated	Analysed	Formulated	Analysed
Crude protein %	12.08	13.24	15.00	14.81

*DeviGain – amino acids glycated onto sugars

Results and discussion

Effect of gender on performance

Throughout the finishing period boars outperformed gilts, with a 5% better growth rate (B= 1282 g/d; G= 1211g /d, P<0.05) and boars were approximately 9% more efficient in terms of food conversion (B= 2.30; G= 2.53, P<0.001).

This would suggest that the requirements of boars and gilts differ in terms of nutrients hence the diets they are offered should be formulated to meet performance potential. This is the case as indicated in Table 2. Gilts performed equally well in terms of growth rate whether offered a 15% CP diet or a 13% CP (15% CP= 1218 g/d; 13% CP= 1250 g/d) throughout the 60 to 140 kg period. Whereas boars grow significantly better when offered a 15% CP diet throughout the period (15% CP= 1347 g/d; 13% CP= 1248 g/d, P<0.05). Interestingly, the differential between performance on the 15% and 13% CP diets for boars remains the same in the late finishing period (100 kg-137 kg) as in the earlier period (60-100 kg) suggesting boars require a 15% CP diet to approximately 140 kg liveweight to meet their potential for lean deposition. This concurs with lots of previous work showing that boars generally have higher growth rate and can use lysine more efficiently than gilts (Yen *et al*. 1986; Campbell *et al*. 1988; Kyriazakis and Emmans, 1992; Van Lunen and Cole, 1996; Moore *et al*. 2013). Indeed, Fuller *et al*. (1995) reported that boars are more sensitive to changes in dietary protein and lysine concentrations than gilts. Interestingly gilts had a numerical deterioration in growth rate at the higher protein level (13% CP= 1250 g/d; 15% CP= 1218 g/d). Excess protein inhibits growth in gilts compared with boars because gilts have lower rates of maximum protein retention than boars, so protein intake becomes excessive at lower levels than for males (Kyriazakis and Emmans, 1992; O'Connell *et al*. 2006). If protein is in excess the pig utilises energy in an attempt to deaminate and eliminate the excess, reducing the energy available for growth functions. Gilts on the 15% CP diet excreted the greatest amount of nitrogen at over 40 g/d and had the poorest growth rate (Tables 2 and 3).

TABLE 2. PERFORMANCE OF BOARS AND GILTS OFFERED DIFFERENT LEVELS OF CP IN DIETS (AFBI TRIAL)

	13:13		15:15			
	Boar	Gilt	Boar	Gilt	SED	P
60-100 kg						
Feed intake (g/d)	2604	2730	2586	2609	61.1	NS
Growth rate (g/d)	1093[a]	1116[a]	1214[b]	1103[a]	32.4	<0.01
FCR	2.38[b]	2.46[b]	2.14[a]	2.40[b]	0.044	<0.01
100-137 kg						
Feed intake (g/d)	3284	3513	3240	3361	108.0	NS
Growth rate (g/d)	1319	1286	1400	1234	50.3	<0.1
FCR	2.51[a]	2.74[b]	2.33[a]	2.76[b]	0.094	<0.05
60-137 kg						
Feed intake (g/d)	2959	3147	2910	3009	77.9	NS
Growth rate (g/d)	1248[a]	1250[a]	1347[b]	1218[a]	34.7	<0.05
FCR	2.38	2.53	2.17	2.50	0.057	<0.1

[a, b] superscripts indicate significance. Means without similar superscripts are significantly different (P<0.05)

TABLE 3. NITROGEN EXCRETION OF BOARS AND GILTS OFFERED DIFFERENT LEVELS OF CP IN DIETS (AFBI TRIAL)

	13:13		15:15			
	Boar	Gilt	Boar	Gilt	SED	P
60-137 kg						
N intake (g/d)	55.2	57.9	61.3	61.8	1.39	NS
N retention (g/d)	28.0[a]	28.6[a]	32.1[b]	28.6[a]	0.83	<0.05
N excretion (g/d)	34.0	36.4	36.3	42.5	1.58	NS
Days to 137 kg	61.5[b]	61.1[b]	56.3[a]	63.1[b]	2.14	<0.05
N excretion per pig (kg)	2.1[a]	2.2[a]	2.1[a]	2.7[b]	0.10	<0.01

[a,b] superscripts indicate significance. Means without identical superscripts are significantly different (P<0.05)

In terms of N excretion, boars on 15% CP had the highest N retention at 32.1 g/d (Table 3). Nitrogen excretion was greater by gilts by approximately 5 g/d. However, this was not significant. When N excretion is calculated allowing for the better performance of boars on the 15% CP diet then it is evident boars can utilise the 15% CP diet with N excretion levels of just over 2 kg per pig for 60-137 kg. This work would suggest, to optimise performance and minimise nutrient excretion then boars and gilts should be kept separately in finishing and offered diets which meet their potential.

Phasing

Boars increased their N retention by 15% in the period 100–137 kg compared to the 60-100 kg period. Overall gilts retained less N than boars but followed the same trend retaining 12% more N in the heavier period compared to the lighter. If N retention continues to rise, should diets be changed to lower nutrient specification as pigs get heavier? Or should they be retained on the same diet? This is dependent on two factors (1) the genetic potential of the animal to deposit protein and (2) the feed intake of the animal.

In the trial at AFBI, changing the diet at 100 kg liveweight from 15% CP to 13% CP was reflected in a significantly poorer growth rate than offering a 15% CP diet throughout, with performance on the 13% CP being intermediate (Table 4). This is similar to the performance on the commercial unit with again the 15% CP having the highest growth rate but this time the 13% CP had the significantly lower growth rate with the 15:13 treatment being intermediate (Table 5). There were no significant differences in FCR in the commercial trial. However, in the AFBI trial the 15% CP treatment had the best FCR (P<0.05, Table 4). Carcass data collected for pigs from the commercial farm showed no significant differences. Kill out averaged 80.3% and P^2 averaged 12.6 mm (Note KO% is high as liveweight was recorded 24 hours before deadweight hence the weight gain for one day was not accounted for and the gastrointestinal tract of these pigs would have been empty).

In the commercial trial offering 13% CP throughout cost 62 p/kg, offering 15% CP throughout cost 63 p/kg and offering 15:13% CP cost 63 p/kg. However, kilograms of gain over the finishing period was 49.4 kg for 13% CP, 53.7 kg for 15% CP and 51.1 kg for 15:13% CP. Therefore, return over feed was highest for the 15% CP at £29.27/pig, it was £27.92/pig for the phased treatment and lowest for the 13% CP at £27.37/pig. (This is based on the 15% CP diet costing £250/tonne, the 13% CP diet costing £238/tonne and price per kg dead weight being £1.55).

The adoption of a two phase feeding regime for finishing pigs is not straightforward and given the slaughter weights up to now, it was not necessary. Published work would suggest that phase feeding, if not beneficial in performance is beneficial financially (Lenis and Jongbloed, 1999; Hong *et al*. 2016). However, work at AFBI taking pigs up to 120 kg liveweight showed no financial benefit in changing the diet to a lower CP at 80 kg dead (Magowan and Ball, 2012). This was due to deterioration in FCR which is in agreement with other work which found poorer FCR with diet change (Leek and O'Doherty, 2003; Beattie *et al*. 2015). In addition, Magowan *et al*. (2016) showed that variability was increased when two diets were used in finishing compared to one single compromise diet. The incongruity in the findings may be explained by work by Leek *et al*. (2006) which showed less difference in performance between single and phased diets when the diet specification was lower. This is supported by the published work that supports phase feeding, this work has all been based on gilts and barrows rather than entire males hence the work is based on lower potential animals with lower diet requirements.

This work shows no benefit in terms of N excretion by phasing for either boars or gilts (Table 6). Numerically, based on this work, the optimum scenario in terms of N excretion is to offer single diets throughout the late finishing period specified at 15% CP for boars and 13% CP for gilts.

TABLE 4. EFFECT OF DIET AND CHANGE OF DIET ON PERFORMANCE AND N EXCRETION (AFBI TRIAL)

	13:13	15:15	15:13	SED	P
60-100 kg					
Feed Intake (g/d)	2667	2597		43.5	NS
Growth rate (g/d)	1105	1159		23.0	<0.05
FCR	2.42	2.27		0.032	<0.001
100-137 kg					
Feed intake (g/d)	3398	3300	3340	76.2	NS
Growth rate (g/d)	1302^{b}	1317^{b}	1240^{a}	35.5	<0.05
FCR	2.63^{ab}	2.54^{a}	2.72^{b}	0.066	<0.05
60-137 kg					
Feed intake (g/d)	3053	2960	2944	54.9	NS
Growth rate (g/d)	1249^{ab}	1282^{b}	1209^{a}	24.5	<0.05
FCR	2.46^{b}	2.34^{a}	2.45^{b}	0.040	<0.01
60-137 kg					
N intake (g/d)	64.7^{a}	70.1^{b}	66.4^{ab}	1.22	<0.001
N retention (g/d)	28.3^{a}	30.3^{b}	29.0^{ab}	0.68	<0.05
N excretion (g/d)	35.2^{a}	39.4b	36.6^{a}	1.12	<0.001
Days to 137 kg	61.3^{ab}	60.2a	63.3^{b}	1.51	<0.1
N excretion per pig (kg)	2.7^{a}	2.4^{b}	2.3^{b}	0.07	<0.01
gN ex/kg gain	28.2	30.7	30.2		

^{a,b} superscripts indicate significance. Means without identical superscripts are significantly different (P<0.05)

TABLE 5. EFFECT OF DIET AND CHANGE OF DIET ON PERFORMANCE AND N EXCRETION (COMMERCIAL UNIT)

	13:13	15:15	15:13	SED	P
60-100 kg					
Feed Intake (g/d)	2416	2456		41.18	NS
Growth rate (g/d)	983^{a}	1045^{b}		12.76	<0.05
FCR	2.46	2.35		0.039	<0.1
100-120 kg					
Feed intake (g/d)	2788	2982	2883	78.15	NS
Growth rate (g/d)	938^{a}	1049^{b}	927^{a}	30.08	<0.05
FCR	2.97	2.84	3.11	0.096	NS
60-137 kg					
Feed intake (g/d)	2539	2663	2569	48.15	NS
Growth rate (g/d)	968^{a}	1052^{b}	1001^{ab}	17.53	<0.05
FCR	2.62	2.53	2.57	0.036	NS
60-137 kg					
N intake (g/d)	55.3	62.2	58.6		
N retention (g/d)	24.9^{a}	26.9^{b}	25.6^{ab}	0.45	<0.05
N excretion (g/d)	30.8^{a}	35.3^{b}	33.0^{ab}	0.84	<0.001
Days to 120 kg	57.3	52.8	55.4		
N excretion per pig (kg)	1.8	1.9	1.8		
gN/kg gain	32	33	33		
N excretion per pig at 137 kg*	2.3	2.4	2.3		

^{a,b} superscripts indicate significance. Means without identical superscripts are significantly different (P<0.05)
*Extrapolated to 137 kg for comparison with AFBI.

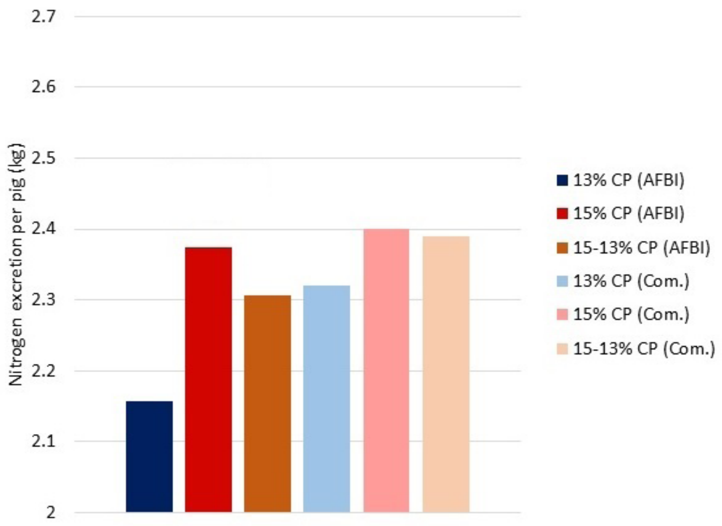

FIGURE 1. COMPARISON OF THE NITROGEN EXCRETION PER PIG BETWEEN AFBI AND A COMMERCIAL UNIT (EXTRAPOLATED TO 137 KG).

Changing the diet at 100 kg liveweight from 15% CP to 13% CP was reflected in a significantly poorer growth rate for gilts (1166 g/d, P<0.05) compared to 15% or 13% CP throughout the 60-137 kg period (Table 6). In boars the 15 to 13% CP change gave comparable growth rates to 13% CP throughout the period. Both treatments 15:13% CP and 13% CP had significantly poorer growth rate than the 15% CP and FCR tended towards the same pattern. FCR for boars during the total finishing period was best on the 15% CP diet at 2.17, whereas the 13% CP diet throughout had a similar FCR to the 15%-13% CP diet (2.38 and 2.34 respectively, P<0.1).

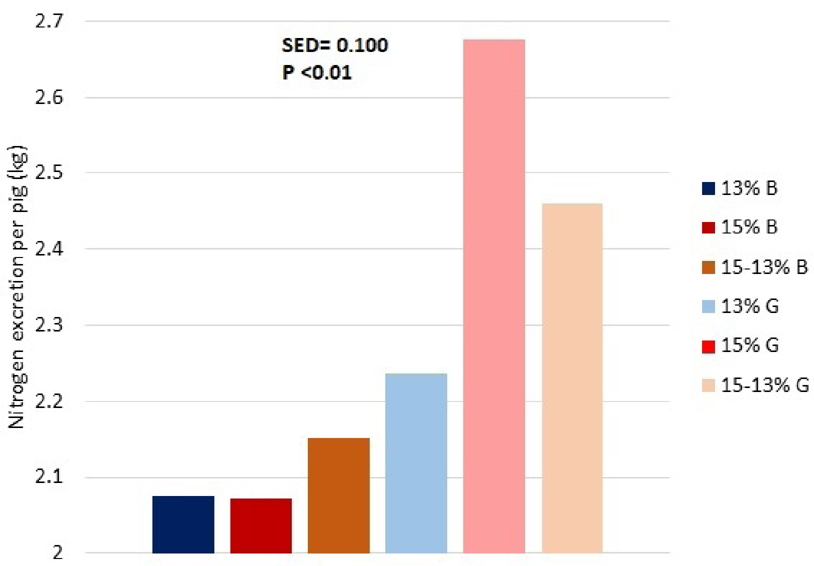

FIGURE 2. NITROGEN EXCRETION PER PIG FOR GENDER, DIET AND CHANGE OF DIET

TABLE 6. EFFECT OF GENDER, DIET AND CHANGE OF DIET ON PERFORMANCE (AFBI TRIAL)

	13% CP		15% CP					
	Boar	Gilt	Boar		Gilt		SED	P
60-100 kg								
Feed Intake (g/d)	2604	2730	2586		2609		61.1	NS
Growth rate (g/d)	1093^{a}	1116^{a}	1214^{b}		1103^{a}		32.4	<0.01
FCR	2.38^{b}	2.46^{b}	2.14^{a}		2.40^{b}		0.044	<0.01
	13:13		15:15		15:13			
	Boar	Gilt	Boar	Gilt	Boar	Gilt		
100-137 kg								
Feed intake (g/d)	3284	3513	3240	3361	3312	3369	108.0	NS
Growth rate (g/d)	1319	1286	1400	1234	1246	1233	50.3	<0.1
FCR	2.51^{ab}	2.74^{c}	2.33^{a}	2.76^{c}	2.69^{bc}	2.75^{c}	0.094	<0.05
60-137kg								
Feed intake (g/d)	2959	3147	2910	3009	2917	2972	77.9	NS
Growth rate (g/d)	1248^{b}	1250^{b}	1347^{c}	1218^{ab}	1251^{b}	1166^{a}	34.7	<0.05
FCR	2.38	2.53	2.17	2.50	2.34	2.56	0.057	<0.1
60-137 kg								
N intake (g/d)	62.7	66.7	69.0	71.3	65.9	68.9	1.73	NS
N retention (g/d)	28.0^{a}	28.6^{ab}	32.1^{c}	28.6^{ab}	30.1^{b}	28.0^{a}	0.96	<0.05
N excretion (g/d)	34.0	36.4	36.3	42.5	35.5	37.7	1.58	NS
Excretion per pig (kg)	2.1^{a}	2.2^{a}	2.1^{a}	2.7^{c}	2.2^{a}	2.5^{b}	0.100	<0.01

^{a,b,c} superscripts indicate significance. Means without identical superscripts are significantly different (P<0.05)

The pig industry has responded to the environmental challenges by reducing crude protein in diets. This work examined the final diet, at the end of the pig's growth curve. At this point lean deposition is beginning to reduce hence the late finish diet is the diet with potential for the lowest crude protein. When formulating to this low level of crude protein any variability in raw material especially cereals and protein sources is going to affect the analysis. This is evident in this piece of work. The agreement between formulated and analysed was perfect for the 15% CP diet but it was approximately 10% too high for the 12% CP diet (formulated 12.08% CP; Analysed 13.24% CP). Hence as the industry pushes towards lower CP diets the need for precision in formulation, analysis and management of performance will become more imperative. For example, the 1.16% difference in dietary CP equates to 5.6 g N excreted per day or 0.35 kg N per pig over the late finish period. However, that is assuming that dropping 1% in dietary CP would give the same performance as the 13% CP diet. Hence the need for precision in terms of performance, management and diet formulation as we endeavour to reduce these last grams of nitrogen excretion. The difference in performance between the research farm and the commercial farm is over 250 g/d. If the pigs on the commercial farm were taken to 137 kg they would have excreted approximately 0.2 kg more nitrogen than the pigs on the research farm (Figure 1). What this shows is that, in terms of nitrogen output from a pig unit, diet formulation and analysis is vitally important but equally important is the performance of the animal on farm. Indeed, large gains can be achieved in reducing N excretion by ensuring optimal animal performance.

Conclusion

Precision feeding is required within the pig industry if N excretion is to be reduced further. This will require precise diet formulation and diet analysis at low crude protein concentrations. In addition, gender, start weights and performance will all have to be accounted for in relation to diet specification.

Summary

- Boars and gilts should be fed separately in finishing as boars require a 15% CP diet throughout the late finishing period and gilts require a 13% CP diet throughout the late finishing period.
- Changing diet during the finishing period lowers growth rate and deteriorates feed efficiency leading to increased excretion
- Performance on farm plays a large role in determining N excretion.

Acknowledgments

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References

Beattie, V.E., Lawrence, E.M.K., Marshall, B., Keenan, J.B., Bradford, R.B., and Magowan, E. (2015). Feeding the finishing pig. *Research to Drive Sustainable Pig Production, Proceedings of a seminar held at AFB*I, 44-50.

Campbell, R.G., Taverner, M.R. and Curic, D.M. (1988). The effect of sex and live weight on the growing pig's response to dietary protein. *Animal Production*, 46:123-130.

Fuller, M.F., Franklin, M.F., McWilliam, R. and Pennie, J. (1995). The responses of growing pigs, of different sex and genotype to dietary energy and protein. *Animal Science*, 60:291-298.

Hong, J.S., Lee, G.I., Jin, X.H. and Kim, Y.Y. (2016). Effect of dietary energy levels and phase feeding by protein levels in growth performance, blood profiles and carcass characteristics in growing-finishing pigs. *Journal of Animal Science and Technology*, 58: 37.

Kyriazakis, I. and Emmans, G.C. (1992). The effects of varying protein and energy intakes on the growth and body composition of pigs. *British Journal of Nutrition*, 68:603-613.

Leek, A.B.G., Hayes, E.T., Curran, T.P., Callan, J.J., Beattie, V.E., Dodd, V.A. and O'Doherty, J. (2006). The influence of manure composition on emissions of odour and ammonia from finishing pigs fed different concentrations of dietary crude protein. *Bioresource Technology*, 98:3431-3439.

Leek, A.B.G and O'Doherty, J.V. (2003). Feeding strategies for meeting the lysine requirements of the growing and finishing pig. *Proceedings of the 54th Annual Meeting of the European Federation of Animal Science*, p86.

Lenis, N.P. and Jongbloed, A.W. (1999). New technologies in low pollution swine diets: Diet manipulation and use of synthetic amino acids, phytase and phase feeding for reduction of nitrogen and phosphorus excretion and ammonia emission. *Asian-Aus Journal of Animal Science*, 12:305-327.

MacNeil MD and Kemp RA, (2015). Genetic parameter estimation and evaluation of Duroc boars for feed efficiency and component traits. *Canadian Journal of Animal Science*, 95:155-159.

Magowan, E. and Ball, M.E.E. (2012). Making the most of feed for finishing pigs. *Pig Research to Improve Sustainability, Proceedings of a seminar held at AFB*I, 89-104.

Magowan, E, Keenan, J. and Beattie, V.E. (2016). Phase feeding groups of pigs representing high or low weight variation. *Proceedings of the 67th Annual Meeting of the European Federation of Animal Science*, 22.

Moore, K.L., Mullan, B.P., Campbell, R.G. and Kim, J.C. (2013). The response of entire male and female pigs from 20 to 100kg liveweight to dietary available lysine. *Animal Production Science*, 53:67-74.

O'Connell, M.K., Lynch, P.B. and O'Doherty, J.V. (2006). Determination of the optimum dietary lysine concentration for boars and gilts penned in pairs and in groups in the weight range 60 to 100kg. *Animal Science*, 82:65-73.

Van Lunen, T.A. and Cole, D.J.A. (1996). The effect of lysine/digestible energy ratio on growth performance and nitrogen deposition of hybrid boars, gilts and castrated males. *Animal Science*, 63:465-475.

Weatherup, R.N., Beattie, V.E., Moss, B.W., Kirkpatrick, D.J., Walker, N. (1998). The effect of increasing slaughter weight on the production performance and meat quality of finishing pigs. *Animal Science* 67: 591-600.

Whittemore, C. (1998). The Science and Practice of Pig Production. *Blackwell science*.

Yen, H.T., Cole, D.J.A and Lewis, D. (1986). Amino acids requirements of growing pigs. The response of pigs from 50 to 90kg live weight to dietary ideal protein. *Animal Production*, 43:155-165.

Dietary crude protein and lysine levels for finishing pigs

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Background

Two of the previous studies by the Pig Research Consortium investigated the effect of dietary lysine level in diets for growing and early finishing pigs (Weatherup *et al*. 2002; Ball *et al*. 2013). Both of these studies demonstrated the importance of supplying adequate lysine (and other amino acids in balance) in maintaining production performance when lowering crude protein (CP) in the diets for younger pigs. However, despite the considerable research conducted on lysine and amino acid levels in younger pigs both by the Consortium and others, there has been less research conducted on heavier pigs and on the cumulative effect of lowering dietary CP and lowering amino acid supply (Soto *et al*. 2019). The work presented in the previous paper on heavy finishing pigs (Beattie *et al*. 2020) also indicated that either 13% CP or 0.9% lysine was insufficient to maintain optimum performance in boars from 60 kg upwards. Therefore, the aim of this trial was to investigate the effect of a low 13% CP diet containing different levels of lysine on performance and N excretion in finishing pigs. A further aim was to determine if CP could be lowered from 15% to 13% for finishing pigs if lysine levels were maintained at higher levels. There is evidence in the literature that even diets that provide adequate amino acids may result in lower performance if dietary CP is below a certain level (Figueroa *et al*. 2002; Soto *et al*. 2018).

Therefore, a trial was designed with the objective to establish the difference between finisher diets at 13% CP with either standard or low lysine levels, and to establish the difference between finisher diets at 13% and 15% CP on the performance of finishing pigs.

Materials and methods

A trial was performed at AFBI Hillsborough pig facilities using a total of 180 pigs. There were six experimental treatments: 1) 13% CP with low lysine, boars; 2) 13% CP with low lysine, gilts; 3) 13% CP with standard lysine, boars; 4) 13% CP with standard lysine, gilts; 5) 15% CP standard lysine, boars; and 6) 15% CP with standard lysine, gilts. The 13% CP, low lysine diet contained 0.88% lysine, the 13% CP, standard lysine diet contained 0.97% lysine and the 15% CP diet contained 1.14% lysine. DeviGain supplied 0.1% of the amino acids. All diets were formulated to contain 14 MJ/kg of digestible energy (DE). Diet formulations are presented in Table 1 and diets were analysed to determine levels of CP, lysine and other amino acids. Crossbred (LW x LR x Danish x Duroc) pigs (n=60, 30 boars and 30 gilts) of similar husbandry background and bodyweight (31.1 ± 6 kg) were selected and assigned to six single-sex pens (10 pigs/pen) at 10 weeks of age using three batches of pigs. Each pen was equipped with an MLP FIRE feeder which recorded individual feed intake and bodyweight at each visit. Pigs were offered a commercial grower diet in pellet form (CP 18.5%, lysine 1.3%, 15.0 MJ/kg DE) until 12 weeks of age. At 12 weeks of age they were offered a pre-finisher diet (CP 16.5%, lysine 1.25%, 14.3 MJ/kg DE) until the average weight of each group was 65 kg. At 65 kg pen average, the pens were assigned to one of the six treatments. Feed intake and bodyweight data from the feeders were used to calculate average daily feed intake (DFI) and linear-regressed average daily gain (LWG) (according to MacNeil and Kemp, 2014) for each individual pig. This was then used to calculate feed conversion ratio (FCR) for each individual pig for the overall finishing period between 65 and 115 kg. The results were analysed as a two factorial arrangement using REML analysis with pig as the experimental unit. Start weight was applied as a covariate for feed intake, LWG and FCR parameters.

Results and discussion

The original design of this experiment was to obtain three treatments with different CP levels: 12%, 13% and 15% CP with the Lys:CP ratio of 0.075. Analysis of the diets (Table 1) showed that the actual CP contents of the 13% and 15% CP diets were very similar to the formulated values. However, it became apparent that a 12% CP level was not possible to achieve in practice while maintaining amino acid balance and adequate energy. All batches of diet formulated at 12% CP turned out to actually be 13% CP with a Lys:CP lower than formulated thus resulting in a low lysine diet. For that reason, one of the treatments is a 13% CP diet with low lysine level. This difficulty in producing very low CP diets has been reported before (e.g. Ball *et al*. 2013) and is an important point to highlight. In theory, the idea of lowering CP levels ever downwards is very attractive from an environmental perspective, but as the CP content of the diet is obviously dictated by the CP content of the dietary ingredients, achieving lower and lower levels is extremely difficult while still maintaining a diet adequate in amino acids and energy. In addition, it must also be remembered that there is always a margin of error on laboratory analysis. Nevertheless, the fact that the analysed levels of 13% and 15% CP diets were identical to the formulated levels and that the formulated and analysed levels of lysine were also identical, gives confidence that the formulation package used was accurate and that we are getting “what it says on the tin” for higher CP diets. Furthermore, for lysine and other essential amino acids, the analysed versus formulated levels were in close agreement which provides further evidence of accurate formulation.

To facilitate their discussion, results comparing the two different lysine levels in 13% CP diets and results comparing the two different CP levels are presented separately.

TABLE 1. FORMULATED AND ANALYSED CP AND LYSINE CONTENTS OF EXPERIMENTAL DIETS

	13% CP / low lysine	13% CP / standard lysine	15% CP
Formulated			
CP	12%	13%	15%
Lysine	0.900	0.975	1.125
Lys:CP ratio	0.075	0.075	0.075
Analysed			
CP	13.2	13.2	15.1
Lysine*	0.88	0.97	1.14
Lys:CP ratio	0.067	0.073	0.075

*Includes 0.1% from DeviGain

Part one – lysine levels in low CP finishing diets for boars and gilts

As has been shown in the previous paper, there was also a strong gender effect on performance (Table 2) with boars significantly outperforming gilts in terms of ADG and FCR. Due to better performance, boars excreted less N on a daily basis and on a per pig basis. The better performance observed by boars was expected due to their ability to utilise protein more efficiently and supports the conclusion by Beattie *et al*. (2020) in the previous paper that boars and gilts should be fed separately.

Also of interest, boars spent significantly more time in the feeder than gilts although total feed intake was not significantly higher. De Haer and De Vriers (1993) reported that boars visited the feeder less but ate more during each visit which may contribute to a more efficient FCR. However, in the current study, there was no evidence to support that feeding behaviour affected the performance of boars or gilts when offered any of the diets. This is in keeping with the findings of Augspurger *et al*. (2002). Nonetheless, the modern electronic feeders used in AFBI record a wide variety of feeding behaviour parameters (e.g. frequency of feeder visits, time in the feeder, time of feeder visit, etc.) and it may be beneficial to explore possible relationships between feeding behaviour and performance further, as there is evidence to indicate possible correlations between feeding frequency and FCR and the interactions between single or mixed-sex housing (Hyun and Ellis 2001; Labroue *et al*. 1994).

TABLE 2. THE EFFECT OF GENDER ON FINISHING PIG PERFORMANCE, N BALANCE AND FEEDING BEHAVIOUR

	Boar	Gilt	SED	P
Pig days 65-115 kg	42.7	45.0	1.42	NS
Intake (65-115 kg) (kg/d)	2.78	2.84	0.048	NS
ADG (65-115 kg) (kg/d)	1.22	1.16	0.024	0.010
FCR (65-115 kg)	2.28	2.45	0.031	<0.001
Lysine intake (g/d) 65-115 kg	22.9	23.4	0.40	NS
CP intake (g/d) 65-115 kg	367	375	6.4	NS
N intake (g/d) 65-115 kg	58.8	60.1	1.03	NS
N retention (g/d) 65-115 kg	31.5	29.8	0.61	0.010
N excretion (g/d) 65-115 kg	27.4	30.3	0.68	<0.001
N excretion kg/pig	1.15	1.36	0.034	<0.001
Total time in feeder/d (hrs)	1.11	1.04	0.037	0.027
Number of visits /d	6.9	7.0	0.38	NS
Time in feeder /visit (mins)	11.17	9.73	0.597	0.011

Pigs performed significantly better on higher lysine diets in terms of FCR (2.30 vs. 2.43, Table 3) suggesting that the lysine content 0.9% and the Lys:CP ratio of 0.067 was too low to drive optimum performance. The better performance resulted in a lower N excretion for pigs offered the higher lysine diet. Again, this is in keeping with the results of the previous paper (Beattie *et al*. 2020). This is a critical finding to highlight as, while it is possible to reduce CP to 13%, the fact that lysine, and by default, the other amino acids was lower in one of the diets, reduced performance and increased N excretion.

Table 4 presents the interaction between gender and lysine level and clearly shows that the performance of boars was adversely affected by lower lysine levels but that gilt performance was not affected by offering the lower lysine diet. The response was most pronounced for ADG and FCR and this was reflected in lower pig days required to reach 115 kg for boars offered the higher lysine diets (41 days vs. 45 days from 65 kg). There was no significant interaction on N excretion on a daily basis but the numerical differences support the effect of gender and lysine level on N balance and, overall, they highlight the need to ensure that performance is optimised to reduce excretion. It has been well established that if lysine and amino acids are not supplied at sufficient levels, optimum performance will not be achieved (e.g. Ball *et al*. 2013) and it can be concluded that the 0.9% total lysine content in the low lysine diet was not sufficient for boars from 65-115 kg and would increase N excretion in Northern Ireland by 146 t per annum (Figure 1). This is a key finding and further highlights the advantage of separating boars and gilts and the potential benefit of offering diets with differing specifications.

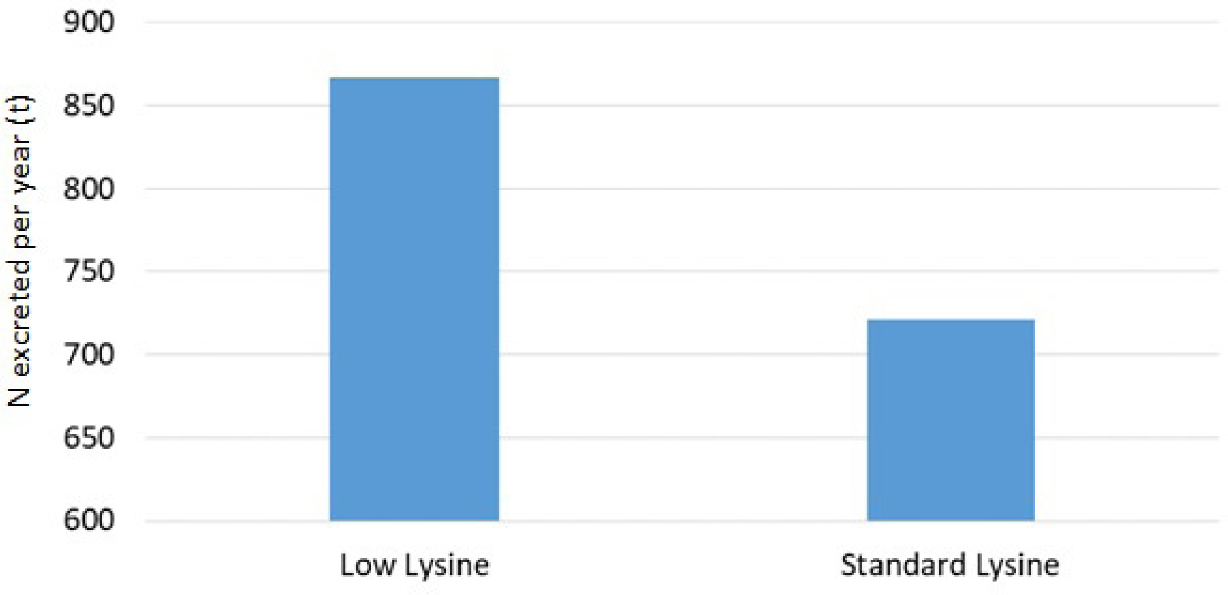
TABLE 3. THE EFFECT OF LYSINE LEVEL ON FINISHING PIG PERFORMANCE, N BALANCE AND FEEDING BEHAVIOUR

	13% CP / low lysine	13% CP / standard lysine	SED	P
Pig days 65-115 kg	44.1	43.7	1.42	NS
Intake (65-115 kg) (kg/d)	2.85	2.77	0.048	NS
ADG (65-115 kg) (kg/d)	1.18	1.21	0.024	NS
FCR (65-115 kg)	2.43	2.30	0.031	<0.001
Lysine intake (g/d) 65-115 kg	22.3	24.1	0.40	<0.001
CP intake (g/d) 65-115 kg	377	365	6.39	NS
N intake (g/d) 65-115 kg	60.4	58.5	1.02	NS
N retention (g/d) 65-115 kg	30.1	31.1	0.61	NS
N excretion (g/d) 65-115 kg	30.2	27.4	0.68	<0.001
N excretion (kg/pig)	1.32	1.18	0.034	<0.001
Total time in feeder/d (hrs)	1.10	1.05	0.037	NS
Number of visits /d	6.8	7.1	0.38	NS
Time in feeder /visit (mins)	10.8	10.1	0.59	NS

TABLE 4. THE INTERACTIVE EFFECT OF GENDER AND DIETARY LYSINE LEVEL ON FINISHING PIG PERFORMANCE, N BALANCE AND FEEDING BEHAVIOUR

	13% CP / low lysine		13% CP / standard lysine		SED	P
	Boar	Gilt	Boar	Gilt		
Pig days 65-115 kg	44.8[b]	43.4[ab]	40.7[a]	46.7[b]	2.00	0.010
Intake (65-115 kg) (kg/d)	2.79	2.91	2.77	2.77	0.068	NS
ADG (65-115 kg) (kg/d)	1.18[a]	1.18[a]	1.27[b]	1.15[a]	0.034	0.016
FCR (65-115 kg)	2.37[b]	2.48[c]	2.18[a]	2.42[bc]	0.044	0.043
Lysine intake (g/d) 65-115 kg	21.7	22.7	24.1	24.1	0.57	NS
CP intake (g/d) 65-115 kg	369	385	365	366	9.0	NS
N intake (g/d) 65-115 kg	59.1	61.7	58.4	58.5	1.45	NS
N retention (g/d) 65-115 kg	30.1[a]	30.1[a]	32.6[b]	29.6[a]	0.86	0.016
N excretion (g/d) 65-115 kg	28.9	31.6	25.9	29.0	0.96	NS
N excretion (kg/pig)	1.25[b]	1.40[c]	1.04[a]	1.33[bc]	0.048	0.035
Total time in feeder/d (hrs)	1.09	1.14	1.10	0.97	0.052	0.015
Number of visits /d	6.7	7.0	7.0	7.1	0.54	NS
Time in feeder /visit (mins)	11.2	11.1	10.4	9.1	0.84	NS

[a,b,c] superscripts indicate significance. Means without identical superscripts are significantly different ($P<0.05$)



*Calculated from N excreted per pig x number of finishing pigs in Northern Ireland (Statistical Review of Northern Ireland Agriculture 2019) (assuming 50% boars)

FIGURE 1. NITROGEN EXCRETED PER YEAR (T) FROM FINISHING BOARS OFFERED LOW AND STANDARD LYSINE DIETS

Offering the 13% CP standard lysine diet resulted in a higher return over feed when compared with offering 13% CP low lysine (Table 5). The difference for boars was approximately £1 per pig and for gilts was £1.70.

TABLE 5. THE ECONOMICS OF OFFERING DIETS DIFFERING IN LYSINE CONTENT TO BOARS AND GILTS

	13% CP / low lysine		13% CP / standard lysine	
	Boar	Gilt	Boar	Gilt
Price per tonne of feed (£)	238	238	242	242
Pig days 65-115 kg	44.8	43.4	40.7	46.7
FCR (65-115 kg)	2.37	2.48	2.18	2.42
p/kg gain	56	59	53	59
Kg of gain (kg)	52.7	51.0	51.8	53.9
Cost of gain (£)	29.51	30.09	27.45	31.80
Income/kg gain dead weight (£)	1.55	1.55	1.55	1.55
Return over feed / pig (£)	32.57	29.99	33.57	31.69

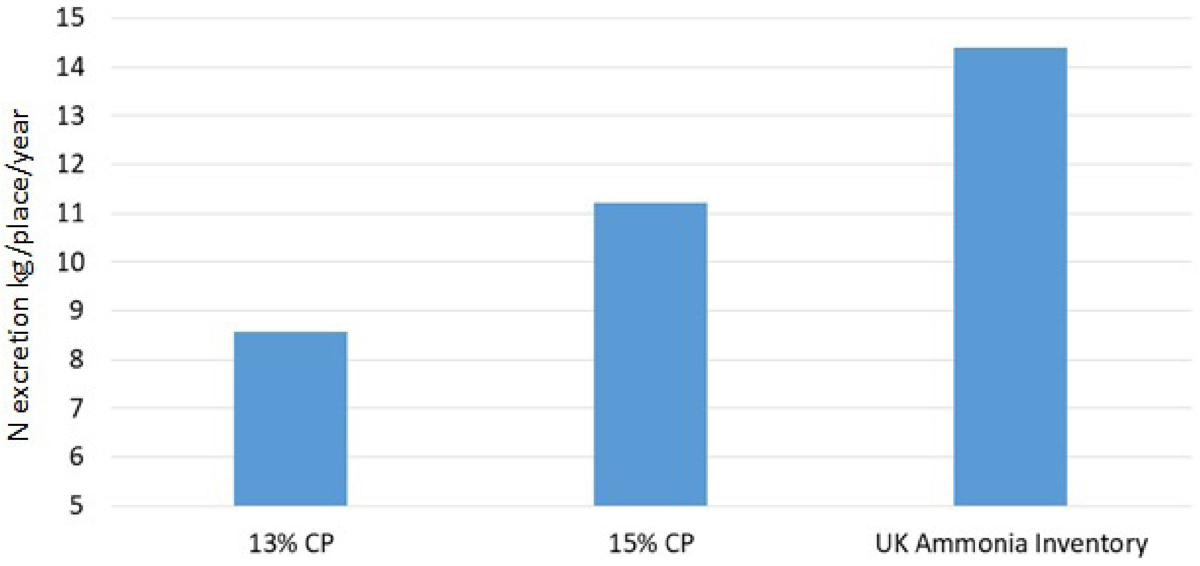
Part two – the effect of low or higher dietary CP in finishing pig performance

Offering lower CP diets balanced with a similar Lys:CP ratio had no detrimental effect on performance in the finishing stage (Table 6). There was no difference in the number of pig days required to reach 115 kg, in feed intake, ADG, FCR or feeding behaviour between pigs offered 13% or 15% CP. However, the lower CP diet resulted in a lower lysine intake, lower N intake and a lower N excretion rate on a daily and on a per pig basis (P<0.001). These findings are in keeping with other studies in the literature and point to potential of reducing dietary CP as a tool to further reduce N excretion (Kerr *et al*. 2003; Ball *et al*. 2013) if production performance is maintained.

TABLE 6. THE EFFECT OF DIETARY CP LEVEL ON FINISHING PIG PERFORMANCE, N BALANCE AND FEEDING BEHAVIOUR

	13%	15%	SED	P
Pig days 65-115 kg	43.7	43.6	1.45	NS
Intake (65-115 kg) (kg/d)	2.77	2.69	0.053	NS
ADG (65-115 kg) (kg/d)	1.21	1.18	0.028	NS
FCR (65-115 kg)	2.30	2.30	0.0371	NS
Lysine intake (g/d) 65-115 kg	24.1	28.0	0.50	<0.001
CP intake (g/d) 65-115 kg	365.6	406.0	7.39	<0.001
N intake (g/d) 65-115 kg	58.5	65.0	1.18	<0.001
N retention (g/d) 65-115 kg	31.0	30.2	0.72	NS
N excretion (g/d) 65-115 kg	27.5	34.9	0.80	<0.001
N excretion (kg/pig)	1.18	1.54	0.042	<0.001
Total time in feeder/d (hrs)	1.05	1.06	0.035	NS
Number of visits /d	7.1	6.8	0.48	NS
Total time in feeder /visit (mins)	10.0	11.2	0.62	0.054

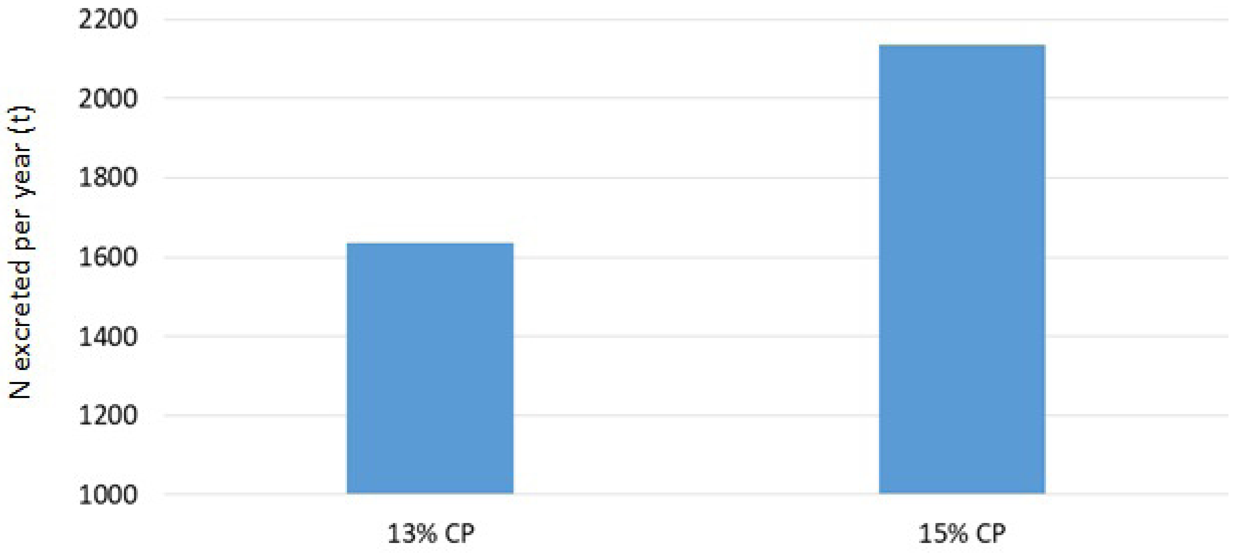
When comparing N excretion on an annual basis and taking account of occupancy rates, offering a 13% CP diet with adequate lysine would reduce N excretion by over 2 kg per pig place per year (Figure 2). It is also of interest to compare the values calculated for N excretion per pig place per year for this study with that reported in the UK Ammonia Inventory (2017). N excretion values for pigs offered either of the diets (13% or 15% CP) was substantially lower than that used in the UK Ammonia Inventory (14.4 kg/place/year cf. 11.2 and 8.6 kg/place/year corresponding to a 22 and 40% reduction respectively). The new data derived from this study is currently being used in conjunction with other AFBI and Pig Research Consortium data to assist in updating the UK Ammonia Inventory to reflect improved pig performance and lower dietary CP levels since the current inventory values were obtained.



*Calculated from N excretion per pig x number of cycles.
Number of cycles = 365/pig days x DEFRA occupancy rate of 87%.

FIGURE 2. COMPARISON OF N EXCRETION ON AN ANNUAL BASIS FROM FINISHING PIGS OFFERED 13% OR 15% CP WITH CURRENT N EXCRETION VALUES IN THE UK AMMONIA INVENTORY (2017).

Reducing dietary CP from 15% to 13% reduced N excretion by 23% which would result in a significant reduction in N excretion from finishing pigs. Figure 3 shows the comparative difference in overall N excretion per year from finishing pigs in NI and 499 t/annum less N would be produced if finishing pigs were offered a 13% CP diet with adequate lysine compared to a 15% CP diet.



*Calculated from N excreted per pig x number of finishing pigs in Northern Ireland
(Statistical Review of Northern Ireland Agriculture 2019)

FIGURE 3. NITROGEN EXCRETED PER YEAR (T) FROM PIGS OFFERED 13 AND 15% CP WITH ADEQUATE LEVELS OF LYSINE AND OTHER AMINO ACIDS

There was no interactive effect (Table 7) with boars and gilts performing equally well when given the same diets. As per previous studies, boars outperformed gilts and as a result excreted less N on a daily and per pig basis. There was an interactive effect on the total time spent in the feeder with boars spending more time in the feeder when offered the 13% CP diet and gilts spending more time in the feeder when offered the 15% CP diet (P<0.001). This is difficult to explain and may suggest some interaction between sex and feeding behaviour (Hyun and Ellis 2001), but from the results of this study, there appears to be no consistent dietary effect on feeding behaviour.

TABLE 7. THE INTERACTIVE EFFECT OF GENDER AND DIETARY CP LEVEL ON FINISHING PIG PERFORMANCE, N BALANCE AND FEEDING BEHAVIOUR

	13% CP		15% CP		SED	P
	Boar	Gilt	Boar	Gilt		
Pig days 65-115 kg	40.7	46.7	40.8	46.4	2.05	NS
Intake (65-115 kg) (kg/d)	2.77	2.77	2.65	2.73	0.075	NS
ADG (65-115 kg) (kg/d)	1.27	1.15	1.23	1.13	0.039	NS
FCR (65-115 kg) (kg/d)	2.18	2.42	2.18	2.42	0.053	NS
Lysine intake (g/d) 65-115 kg	24.1	24.1	27.6	28.4	0.70	NS
CP intake (g/d) 65-115 kg	365.8	365.5	400.1	411.9	10.44	NS
N intake (g/d) 65-115 kg	58.5	58.5	64.0	65.9	1.67	NS
N retention (g/d) 65-115 kg	32.6	29.5	31.5	29.0	1.01	NS
N excretion (g/d) 65-115 kg	25.9	29.0	33.0	36.9	1.14	NS
N excretion (kg/pig)	1.04	1.32	1.39	1.69	0.059	NS
Total time in feeder/d (hrs)	1.13c	1.02ab	0.97a	1.11bc	0.050	<0.001
Number of visits /d	7.0	5.9	7.1	7.6	0.67	0.092
Time in feeder /visit (mins)	11.0	12.0	9.1	10.3	0.873	NS

As presented in Table 8, offering diets containing 15% CP to both boars and gilts resulted in less return over feed costs per pig. This is due to the higher cost to produce a 15% CP diet and equates to £2.50 and £2.89 less return over feed costs for boars and gilts respectively.

TABLE 8. THE ECONOMICS OF OFFERING DIETS DIFFERING IN LYSINE CONTENT TO BOARS AND GILTS

	13% CP		15% CP	
	Boar	Gilt	Boar	Gilt
Price per tonne of feed (£)	238	238	250	250
Pig days 65-115 kg	40.7	46.7	40.8	46.4
FCR (65-115 kg)	2.18	2.42	2.18	2.42
p/kg gain	52	57	55	61
Kg of gain (kg)	51.7	53.8	50.2	52.5
Cost of gain (£)	26.88	30.67	27.61	32.03
Income/kg gain dead weight (£)	1.55	1.55	1.55	1.55
Return over feed / pig (£)	34.02	32.71	31.52	29.82

On-farm performance variability

The previous paper by Beattie *et al*. (2020) has highlighted the difference in production performance of pigs on trial at AFBI or on trial at a commercial farm. this performance variability across different farms has been reported previously and is not unexpected (Weatherup *et al*. 2002). The lower performance on-farm has important implications for N excretion and for the adoption of lower CP diets. Table 9 presents the difference in performance of pigs offered the 15% CP diet at AFBI and on the commercial farm. Intake and ADG were 5% and 18% higher for pigs on the AFBI trial compared to pigs on-farm and pigs at AFBI were 11% more efficient at converting feed to gain. While this was not a controlled trial to compare performance between farms and there were many differences in the studies, the figures provide further evidence of the variability in performance across farms in Northern Ireland. This lower performance translated to a 6% increase in N excretion per day on the commercial farm showing the need to maintain performance to ensure N excretion is kept to a minimum.

TABLE 9. COMPARISON OF PRODUCTION PERFORMANCE AND N EXCRETION FROM PIGS ON TRIAL AT AFBI AND ON A COMMERCIAL FARM OFFERED A DIET CONTAINING 15% CP

	AFBI (65-115 kg)	Commercial farm (60-120 kg)
Intake (kg/d)	2.69	2.57
ADG (kg/d)	1.18	1.00
FCR	2.30	2.57
N excretion (g/d)	33.5	35.3

Offering the lower CP diet (13%) with standard lysine maintained performance on the AFBI trial but there is a danger that if this diet was offered on all farms with finishing pigs in Northern Ireland, the lower intake seen on commercial farms would result in amino acid supply being limited and ultimately lead to a drop in performance that would cause an increase in N excretion. It can be concluded that 13% CP with standard lysine and other amino acids is a target level to potentially achieve on farms with good performing pigs but that careful consideration must be given to the performance of pigs before this level is adopted across the board.

Summary

- Boars perform better and excrete less N and therefore should be fed separately to gilts to enable better flow management.

- Boars require a higher level of lysine (and other amino acids) than gilts.

- A 13% CP diet containing low total lysine (0.9%) is adequate for gilts from 65-115kg but will reduce performance in boars and increase N excretion by 17% (or 146 t/year).

- A 13% CP diet containing standard (0.97%) lysine is adequate for boars and gilts and results in better economic return over feed.

- Reducing dietary CP in diets for finishing pigs from 15% to 13% with standard lysine (0.97%) would maintain performance and reduce N excretion by 23% (or 499 t/annum).

- However, it must be remembered that these diets were offered to pigs in AFBI with higher intakes than on the commercial farm. While this study shows that it is possible to lower finishing diets from 15% to 13% CP there is a risk that such low dietary CP with feed intakes would reduce intake of amino acids to insufficient levels and thus reduce performance. This reduction in performance would ultimately increase N excretion despite the lower CP diet. Therefore, it can be concluded that 13% CP for finishing diets is a potential target but there is more work to be done to improve the overall performance of pigs before this can be recommended across the industry.

- N excretion values for pigs offered either of the diets (13% or 15% CP) was substantially lower than that used in the UK Ammonia Inventory. The new data derived from this study is currently being used in conjunction with other AFBI and Pig Research Consortium data to assist in updating the UK Ammonia Inventory which will bring important benefits to the industry.

Acknowledgments

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References

Augspurger, N.R., Ellis, M., Hamilton, D.N., Wolter, B.F., Beverly, J.L. and Wilson, E.R. (2002). The effect of sire line on the feeding patterns of grow-finish pigs. *Applied Animal Behaviour Science* 75:103-114.

Ball, M. E. E., Magowan, E., Beattie, V. E., McCracken, K. J., Henry, W., Smyth, S., Bradford, R., Gordon, F. J., Mayne, C. S. (2010). The effect of dietary energy source on performance and nutrient digestibility in growing pigs. *Journal of Animal and Feed Sciences*, 19(3):408-417.

Commission Regulation (EU) No 939/2010 (2010). *Official Journal of the European Union*. Amending annex to Regulation (EC) No 767/2009.

De Haer, L.C.M and De Vries, A.G. (1993). Effects of genotype and sex on the feed intake pattern of group housed growing pigs. *Livestock Production Science*, 36:223-232.

Figueroa J. L. Lewis, A.J., Miller, P.S., Fischer, R.L., Gómez, R.S. and Diedrichsen, R.M. (2002). Nitrogen metabolism and growth performance of gilts fed standard corn-soybean meal diets or low-crude protein, amino acid-supplemented diets. *Journal of Animal Science*, 80:2911–2919.

Hyun, Y. and Ellis, M. (2001). Effect of group size and feeder type on growth performance and feeding patterns in growing pigs. *Journal of Animal Science*, 79:803-810.

Labroue, F., Gueblez, R. and Sellier, P., Meunier-Salaun, M.-C. (1994). Feeding behaviour of group-housed Large White and Landrace pigs in French central test stations. *Livestock Production Science*, 40:303-312.

MacNeil MD and Kemp RA, (2015). Genetic parameter estimation and evaluation of Duroc boars for feed efficiency and component traits. *Canadian Journal of Animal Science*, 95:155-159.

Magowan, E., McCann, M.E.E., Beattie, V.E., McCracken, K.J., Henry, W., Smyth, S., Bradford, R., Gordon, F.J., and Mayne, C.S. (2007). Investigation of growth rate variation between commercial pig herds. *Animal*, 1: 1219-1226

Magowan, E., Smyth, S., McCracken, K.J. Gordon, F.J., Gordon, A, Hawe, M., Bradford, R. and Beattie, V.E. (2015) The variation in finishing pig feed conversion efficiency between and within herds. Proceedings of a conference held at AFBI, Hillsborough pp 70.

Sevillano, C.A., Nicolaiciuc, C.V., Molist, F., Pijlman, J. and Bergsma, R. (2018). Effect of feeding cereals–alternative ingredients diets or corn–soybean meal diets on performance and carcass characteristics of growing–finishing gilts and boars. *Journal of Animal Science*, 96:4780-4788.

Soto, J.A., Tokach, M.D., Dritz, S.S., Woodworth, J.C., DeRouchey, J.M., Goodband, R.D. and Fangzhou, W. (2019). Optimal dietary standardized ileal digestible lysine and crude protein concentration for growth and carcass performance in finishing pigs weighing greater than 100 kg. *Journal of Animal Science*, 97:1701–1711.

Soto, J. A. (2018). The effects of soybean meal concentration, dietary electrolyte balance, choline, and potassium supplementation on growth and carcass performance in 110 kg and heavier finishing pigs. PhD diss., Kansas State University, Manhattan, KS.

Statistical Review of NI Agriculture (2019). https://www.daera-ni.gov.uk/sites/default/files/publications/daera/Stats%20Review%202019%20final.pdf

Weatherup, R.N., Beattie, V.E., McCracken, K.J., Henry, R.W., McIlroy, S.G. and Smyth, S. (2002). The effects of energy and lysine concentrations in grower diets for pigs on performance from 8 to 12 weeks of age. *Irish Journal of Agricultural and Food Research*, 41:95–104.

Effect of nutrition on pig pen odour

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Background

The odour emitted from pig houses can be offensive to neighbours. Odour emissions are, therefore, an environmental burden and inhibit the economic growth of the NI (and UK) pig supply chain. Pig odour can be extremely offensive to residences close to pig businesses. As such it is legislated for under EU IPPC legislation, which dictates that pig units must achieve 'under 3 odour units' at the nearest recipient.

The compounds contributing to pig-house odour include acids, indoles, phenols, sulphur compounds and certain amines (Farmer *et al*. 2015; Magowan *et al*. 2015). Many of the above compound classes are derived from microbial action in the intestine or faeces of the animal as illustrated in Figure 1 (Le *et al*. 2005; Le *et al*. 2007; Mackie, 1994; Spoelstra, 1980). Any mitigation measures will need to consider the impact on all these compound classes.

Despite the importance of the gut microflora in pig-house odour, there is a lack of research in the impact of pig diets on the production of volatile odour compounds. There is some evidence to demonstrate that reducing the crude protein content of the diet reduces ammonia emissions (Webb *et al*. 2014) and may reduce odour in some circumstances although odour can increase again when crude protein levels are very low (Le *et al*. 2005, 2007, 2008, 2009). Furthermore, as shown in the previous paper on ammonia emissions (Ball *et al*. 2020) the relationship between ammonia and odour was weak. However, there has been less work conducted on the role of fibre and fat on pig-house odour and the relationship is not understood. Dietary fibre and fat have been reported to influence the microbiota of the intestinal tract thus positively impacting on odour and ammonia output (Agyekum *et al*. 2017), but the interactive effect of fibre and fat was not reported. Fibre has been reported to reduce performance through decreased intake and digestibility (Gao *et al*. 2015) but the effect of the type of fibre (digestible or indigestible) within feed ingredients has not been well established.

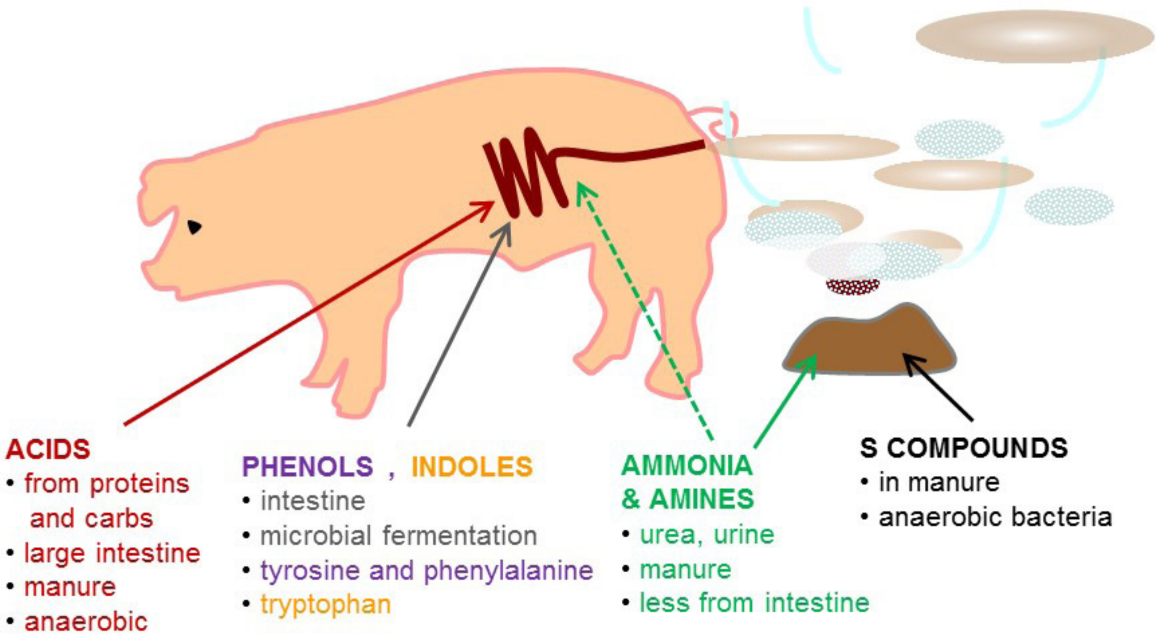

FIGURE 1: MAIN ODOUR COMPOUND CLASSES AND THEIR ORIGIN

As part of a project funded via the Agri-Food Competence Centre, a study was conducted to evaluate the impact of fat and different types of fibre in the diet on the odour compounds from the pigs and their faeces.

Materials and methods

The trial was conducted under the confines of the Animals (Scientific Procedures) Act 1986 and procedures were approved by the AFBI Hillsborough Animal Welfare and Ethical Review Body.

Boar pigs (Dan Duroc x (Large White x Landrace)) were selected at weaning (28d) across two time batches. From each time batch, three sows which had not received any medical treatment during gestation, farrowing or lactation were selected and 24 boar pigs were mixed from the three litters. They were housed in standard grower accommodation with plastic slatted floors and a minimum space allowance of 0.38 m^2/pig. Pigs were allocated 4 kg/pig of starter 1 diet followed by 8 kg/pig of starter 2 diet and then offered medicated grower diet until 11 weeks of age and unmedicated grower diet until 14 weeks of age. At 10 weeks, pigs were transferred to individual pens where they acclimatised until 14 weeks of age and then 18 pigs per batch were assigned to one of the six treatment diets (Table 1) resulting in 6 pigs/treatment. The higher fat levels in diets 1, 4 and 5 were achieved through the addition of soya oil, the higher indigestible fibre in diets 1 and 2 was mainly from wheatfeed/pollard and Maize DDGS, diets 5 and 6 with high digestible fibre had a higher content of sugar beet pulp, while diets 3 and 4 with low fibre and high starch had more barley and less maize than the other diets.

Individual pig performance (daily feed intake (DFI), average daily gain (ADG) and feed conversion ratio (FCR)) were determined for three weeks. After three weeks on the treatment diets, pigs were transferred to individual respiration chambers and after ca. 24 hrs in the chambers, the photoacoustic analyser recorded ammonia production for a total of ca. 73 hrs. At ca. 28 hours analyses were conducted for hydrogen sulphide and odour samples were collected through a PTFE tube into sample bags (Naphlan NA) held in a partially evacuated rigid barrel (BSEN13725:2003). The odour samples were later analysed for odour emissions by olfactometry. At ca. 36 hours in the chambers, the air was sampled for volatile compounds on to Tenax traps, and the samples analysed by gas-chromatography-mass spectrometry. Dry matter intake (DMI) and water usage were recorded over the four days the pigs were in the chambers. After removal from the chamber, slurry production from each pig was measured and samples of slurry stored in sealed containers for 12 weeks and then frozen prior to odour analysis.

TABLE 1. SUMMARY OF DIET FORMULATIONS AND MAIN INGREDIENT INCLUSIONS

Diet No.	Description	Oil A %	Fibre %	DE PIG MJ/kg	Starch %	Cereal inclusion %	C By-products %
1	Hi Fibre (indigestible), high fat	4.8	6.0	13.8	37.6	59.8	20.0
2	Hi Fibre (indigestible), low fat	2.9	6.1	13.3	38.8	61.8	20.0
3	Low Fibre/Hi Starch, low fat	2.1	3.4	13.8	45.4	79.4	5.0
4	Low Fibre/Hi Starch, high fat	4.0	3.4	14.3	44.5	77.8	4.9
5	Hi Fibre (digestible), high fat	3.5	6.0	13.8	38.9	64.8	0
6	Hi Fibre (digestible), low fat	2.1	6.1	13.4	39.6	66.2	0

Results and discussion

Diets were formulated to contain differing levels of fibre and fat and Table 2 shows that, when analysed, the levels of fat and fibre were close to formulated levels.

TABLE 2. ANALYSIS OF DIETS, HIGHLIGHTING DIFFERENCES IN FAT CONTENT, FIBRE AND STARCH

Diet No.	Description	Oil %	Protein %	Fibre %	Moisture %	Non-fibre carbohydrate*
1	Hi Fibre (indigestible), high fat	5.6	14.8	6.8	12.8	55.9
2	Hi Fibre (indigestible), low fat	3.5	15.1	6.1	13.3	57.7
3	Low Fibre/Hi Starch, low fat	2.3	15.1	4.1	15.1	59.4
4	Low Fibre/Hi Starch, high fat	4.3	14.8	3.9	13.4	59.7
5	Hi Fibre (digestible), high fat	4.1	14.8	6.6	12.4	57.8
6	Hi Fibre (digestible), low fat	2.3	16.2	7.0	13.4	55.9

* Calculated as remainder

Due to the use of environmental chambers, the numbers of pigs used in this study were necessarily small, and any effects on performance will need to be confirmed with larger numbers. However, there were some interesting trends. There were only minor effects of the dietary treatments on feed intake and growth parameters. There was an interactive effect (P<0.05) of fibre level/source and fat addition on DFI and ADG (Table 3), which showed that DFI of pigs offered the low fibre diet with additional fat was increased whereas fat addition had no significant effect on DFI of pigs offered diets high in digestible or indigestible fibre. ADG was increased when fat was added to low fibre and high digestible fibre (P<0.05) but not when fat was added to diets high in indigestible fibre. FCR was not significantly different across treatments. There was no significant effect of fibre level/source or fat addition on ammonia, odour emissions, water intake or slurry output (Table 3). However, there was a tendency (P<0.06) for water intake and slurry output to be lower for pigs offered diets containing higher levels of fat.

The effects of diet on performance suggest that varying fibre level/source and fat level impacts on both feed intake and ADG. It is difficult to conclude if the differences observed were intake driven or a result of improved efficiency as there were wide variations in FCR which were non-significant. However, the results suggest that diets high in digestible fibre require additional fat to maintain intake and ADG in finishing and that diets low in fibre should contain high fat addition which is reflective of current industry practice.

TABLE 3. THE EFFECT OF FIBRE LEVEL, FIBRE TYPE AND FAT LEVEL ON PERFORMANCE, ODOUR AND AMMONIA EMISSIONS

Parameter measured[$]	Low fat			High fat			Effect of fibre		Effect of fat		Interaction	
	Low fibre	High I-fibre*	High D-fibre*	Low fibre	High I-fibre	High D-fibre	SEM	P	SEM	P	SEM	P
Diet number	3	2	6	4	1	5						
DFI (g/d)	2.68[a]	3.02[bc]	2.85[ab]	3.18[c]	2.82[ab]	3.00[bc]	0.067	NS	0.054	0.073	0.096	0.007
ADG (g/d)	1.24[a]	1.33[ab]	1.19[a]	1.41[b]	1.23[a]	1.40[b]	0.031	NS	0.038	0.067	0.055	0.026
FCR	2.16	2.29	2.39	2.27	2.31	2.15	0.059	NS	0.048	NS	0.085	0.115
Ammonia emission (mg/hr)	192	86	128	209	109	107	36.0	0.121	30.0	NS	50.3	NS
Odour emission (OuE/Sec)	1.62	1.39	1.49	1.72	1.71	1.33	0.185	NS	0.154	NS	0.258	NS
Hydrogen sulphide (mg/hr)	2.03	0.54	1.79	0.73	0.64	0.87	0.498	NS	0.407	NS	0.702	NS
Water intake (L/day)	6.40	5.37	6.95	4.86	5.37	4.82	0.526	NS	0.437	0.054	0.734	NS
Slurry output (L/day)	2.32	2.30	3.20	2.10	2.02	1.62	0.309	NS	0.257	0.059	0.526	NS

* I-fibre; D-fibre = Indigestible and Digestible fibre.
$ DFI = daily feed intake; ADG = average daily gain; FCR = feed conversion ratio
[a,b,c] Values in the same row which do not share a common superscript are significantly different (P<0.05)

The results in Table 3 show that there was no significant effect of diet on odour emissions, ammonia or hydrogen sulphide. The high values for SEM show that this was due to a high level of individual pig variability. However, while odour emissions were equally variable for all treatments (Figure 2), there was an apparent difference in the distribution of the data for ammonia and hydrogen sulphide emissions (Figures 3, 4). Pigs offered diets 1 and 2 with high indigestible fibre, resulted in consistently low levels of ammonia and hydrogen sulphide in the pig chambers, though these were not significantly different from the more variable results from the other diets.

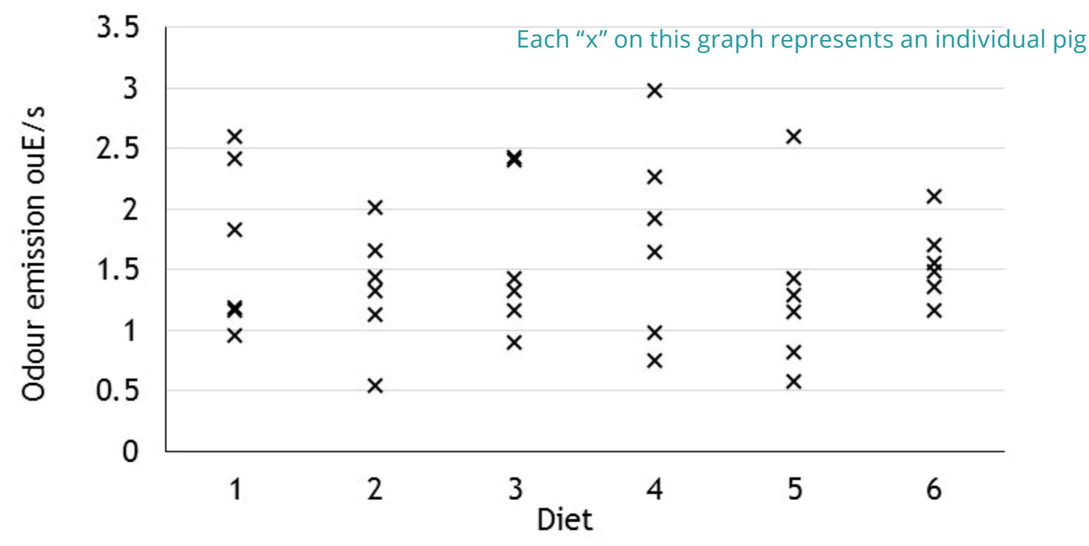

FIGURE 2. EFFECT OF DIET ON ODOUR EMISSIONS

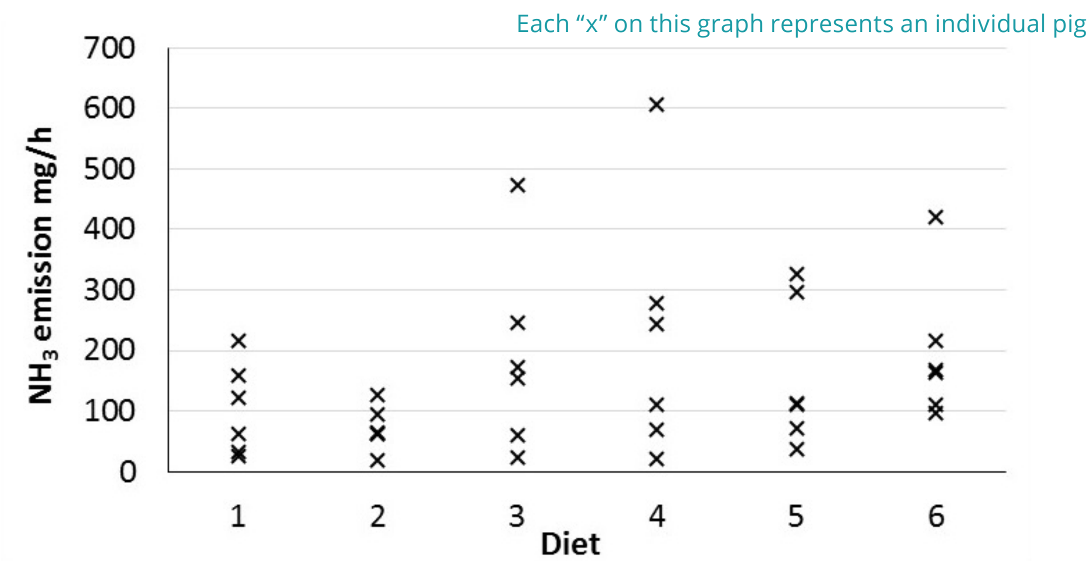

FIGURE 3. EFFECT OF DIET ON AMMONIA EMISSIONS

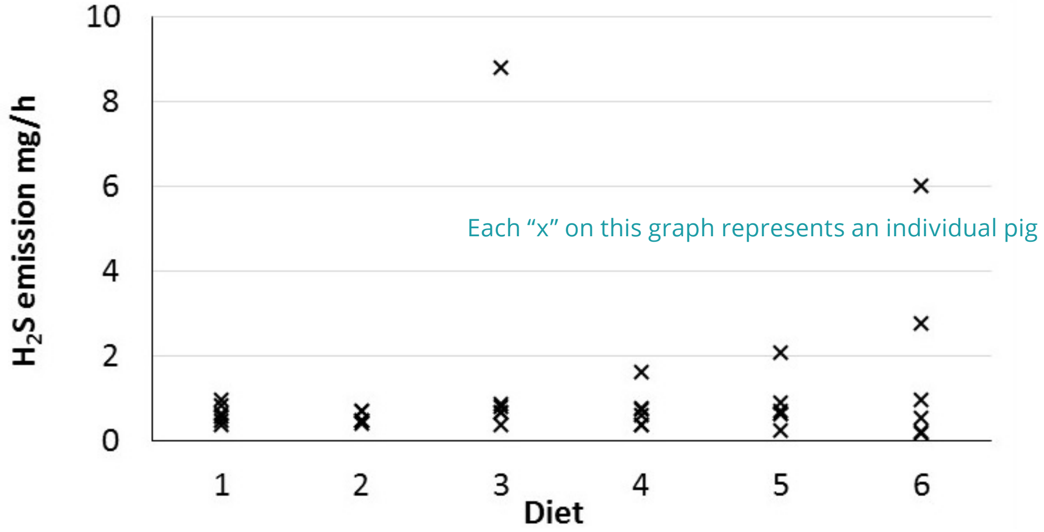

FIGURE 4. EFFECT OF DIET ON HYDROGEN SULPHIDE EMISSIONS

Few of the compounds associated with odour from pig houses showed significant differences between treatments. Figures 5 a-c show the effect of diet on three groups of compounds known to contribute to pig-house odour.

Only one of the short chain acids was significantly affected by diet, though the results showed considerable variation between animals. Pentanoic acid was highest in the pens with pigs on a high digestible fibre and lowest from those with high digestible fibre. Dimethyl disulphide and indole were highest from pigs on a high starch, low fibre diet.

Skatole, a compound with an odour often described as "pig slurry", is the only compound which showed a significant effect of fat but this was inconsistent: pigs on the high indigestible fibre gave higher levels with more fat and those on a high starch diet showed higher levels of skatole from the lower fat diet.

Analyses of the slurry after storage for 12 weeks showed fewer significant differences, but demonstrated that the prevalence of sulphur compounds and phenols increases with time.

In conclusion, while fat had little effect on any measures of odour, there is some evidence that the type and concentration of dietary fibre may influence the odours emitted from the pig faeces.

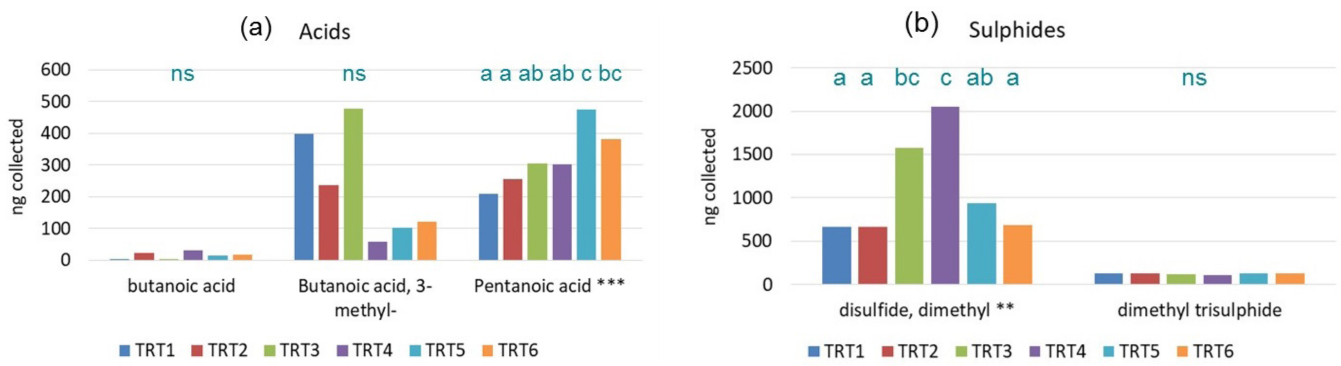

FIGURE 5 (A-C). SIGNIFICANT EFFECTS OF TREATMENT ON VOLATILE COMPOUNDS COLLECTED FROM CHAMBERS (CONTINUED OVER PAGE)

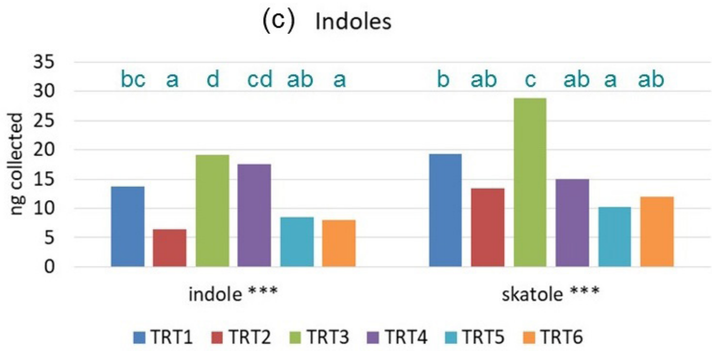

FIGURE 5 (A-C). SIGNIFICANT EFFECTS OF TREATMENT ON VOLATILE COMPOUNDS COLLECTED FROM CHAMBERS (CONTINUED OVER PAGE)

Summary

- The pigs offered the diets in this trial were housed individually and performance was monitored for only a three week period and it will therefore be necessary to validate these results on-farm which is part of phase two of this project. The results of this current trial show that pigs were performing well and were fit to enter the respiration chambers to ascertain the effect of fat and fibre on odour and ammonia emissions. The performance results suggest that diets high in digestible fibre require additional fat to maintain intake and ADG in finishing and that diets low in fibre should contain high fat addition which is reflective of current industry practice.
- There were no significant effects of fibre or fat on the odour emissions or ammonia or hydrogen sulphide emissions. However, higher levels of indigestible fibre resulted in reductions in variability in ammonia and hydrogen sulphide emission, with fewer high values.
- There were significant differences in odorous compounds from pigs offered diets differing in fibre content but not fat content. This includes sulphides and skatole, compounds that contribute to pig-house odour and pork flavour/off-flavour.
- The effects for each dietary fibre type may be summarised:
  - Diets high in indigestible fibre resulted in odours low in acids and sulphides and with fewer elevated levels of ammonia and hydrogen sulphide emitted.
  - Diets high in starch and low in fibre gave odours high in sulphides, indole and skatole and variable emissions of hydrogen sulphide and ammonia.
  - Diets high in digestible fibre gave odours low in indoles and sulphides and variable emissions of hydrogen sulphide and ammonia.

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References

Agyekum, A.K. and Nyachoti, C.M. 2017. Nutrient digestibility, digesta volatile fatty acids, and intestinal bacterial profile in growing pigs fed a distillers dried grains with solubles containing diet supplemented with a multi-enzyme cocktail. *Engineering* 3: 716-725.

Farmer, L.J., Kennedy, J.T. and Magowan, E. (2015) Pig-house odours – a review using odour activity values. In: *Proceedings of the International Congress of Meat Science and Technology*, Clermont Ferrand, France.

Gao, L., Chen, L., Huang, Q., Meng, L., Zhong, R., Liu, C., Tang, X., and Zhang, H. 2015. Effect of dietary fiber type on intestinal nutrient digestibility and hindgut fermentation of diets fed to finishing pigs. *Livestock Science*, 174: 53-58.

Le, P.D., Aarnink, A.J., Ogink, N.W., Becker, P.M. and Verstegen, M.W. (2005). Odour from animal production facilities: its relationship to diet. *Nutrition Research Reviews*, 18(01): 3-30.

Le, P.D., Aarnink, A.J.A. and Jongbloed, A.W. (2009). Odour and ammonia emission from pig manure as affected by dietary crude protein level. *Livestock Science*, 121(2-3): 267-274.

Le, P.D., Aarnink, A.J.A., Jongbloed, A.W., van der Peet-Schwering, C.M.C., Ogink, N.W.M. and Verstegen, M.W.A. (2008). Interactive effects of dietary crude protein and fermentable carbohydrate levels on odour from pig manure. *Livestock Science*, 114(1): 48-61.

Le, R.D., Aarnink, A.J.A., Jongbloed, A.W., Van der Peet-Schwering, C.M.C., Ogink, N.W.M. and Verstegen, M.W.A. (2007). Effects of dietary crude protein level on odour from pig manure. *Animal*, 1(5): 734-744.

Mackie, R.I. 1994. Microbial production of odor components. in: *International round table on swine odor control*. Ames, IA, USA, 18-19.

Magowan, E., Kennedy, T., Mansoor, F. and Farmer, L.J. (2015). Ammonia and odour abatement methods for the NI pig industry. DAERA E&I Project 12/4/03 report, April 2015

Spoelstra, S.F. 1980. Origin of objectionable odorous components in piggery wastes and the possibility of applying indicator components for studying odor development. *Agriculture and Environment*, 5(3): 241-260.

Webb, J., Broomfield, M., Jones, S. and Donovan, B. (2014). Ammonia and odour emissions from UK pig farms and nitrogen leaching from outdoor pig production. A review. *Science of the Total Environment*, 470 – 471: 865 – 875.

Appendix – diet formulations

TABLE 1. INGREDIENT COMPOSITION OF EXPERIMENTAL DIETS USED IN "TARGETING NUTRITION TO REDUCE NITROGEN EXCRETION- STEP 1"

	High protein (22.5%)				Low protein (19.0%)			
Energy, MJ/kg	15.4	14.4	13.4	12.4	15.4	14.4	13.4	12.4
Ingredient, g/kg								
Maize	-	-	-	-	250	-	-	-
Barley	85	196	47	352	-	273	238	392
Wheat	500	450	400	-	435	450	400	25
Wheat middlings	-	-	238	250	-	-	95	250
Grain screenings	-	-	-	75	-	-	8	75
Hipro soybean	268	283	246	249	147	199	191	185
Full fat soybean	50	-	-	-	75	-	-	-
Herring	25	25	25	25	25	25	25	25
Cane molasses	-	-	20	20	-	-	20	20
Soya oil	40	20	-	-	40	20	-	-
Fat blend	5	-	-	-	-	8	-	-
Lysine HCL	3	2	2	2	2	2	1	1
DL methionine	0.7	0.8	0.9	1.2	0.4	0.2	0.2	0.4
L threonine	0.7	0.8	1.0	1.0	0.7	0.5	0.5	0.5
Limestone	5	5	10	17	4	5	7	16
Dicalcium phosphate	10	10	2	1	13	11	8	2
Salt	2	3	2	2	3	2	2	2
Min/vits	5	5	5	5	5	5	5	5

TABLE 2. INGREDIENT COMPOSITION OF EXPERIMENTAL DIETS USED IN "TARGETING NUTRITION TO REDUCE NITROGEN EXCRETION- STEP 2"

	8.0 g/kg available lysine (g/kg CP)					9.0 g/kg available lysine (g/kg CP)				
Crude protein, %	13.6	14.9	16.2	17.5	18.8	13.6	14.9	16.2	17.5	18.8
Ingredient, g/kg										
Barley	193	326	248	263	186	337	336	303	272	240
Wheat	400	356	400	330	400	296	347	346	344	322
Maize	73	-	-	20	-	100	-	-	-	19
Pollard	150	150	150	150	150	23.6	150	150	150	150
Oat feed	27		4			50				
Soybean meal	73	98	137	179	199	95	93	133	173	214
Full fat soybean	-	-	-	-	19.9	-	-	-	-	-
Molaferm	10	10	10	10	10	10	10	10	10	10
Vegetable oil blend	40.0	31.1	25.1	24.2	13.3	50.0	33.9	29.8	25.9	22.6
Lysine HCL	4.8	3.7	2.5	1.1		5.8	5.2	3.9	2.6	1.3
DL methionine	0.7	0.4	0.2	-	-	1.4	1.0	0.6	0.4	0.1
L threonine	1.6	1.1	0.5	-	-	2.1	1.8	1.2	0.6	-
Tryptophan	0.3	0.1	-	-	-	0.6	0.3	0.2	-	-
Limestone	16.2	13.8	13.7	13.9	13.9	14.4	13.7	13.8	13.9	13.9
Mono DCP	3.7	2.3	1.9	1.1	0.7	6.8	2.4	1.8	1.2	0.5
Salt	1.5	1.8	2.2	2.7	3.1	2.2	1.3	1.8	2.2	2.7
Min/vits	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0

TABLE 3. INGREDIENT COMPOSITION OF EXPERIMENTAL DIETS USED IN "TARGETING NUTRITION TO REDUCE NITROGEN EXCRETION- STEP 3"

Crude protein, %	17.5%	15%	15%	15%	15% + DeviGain	15% + DeviGain (-10% amino acids)
Ideal protein formulated to:		Meth, Thr, Tryp, Val, Iso , Arg	Meth, Thr, Tryp	Meth, Thr	Meth, Thr, Tryp, Val, Iso, Arg	Meth, Thr, Tryp
Ingredient, g/kg						
Barley	300	300	211	215	300	300
Wheat	100	172	245	241	155	143
Maize	270	300	300	300	300	300
Pollard	50	15.2	50	50	50	50
Rapeseed	50	-	50	50	-	50
Hipro soybean	190	137	102	102	138	109
Vegetable oil	10	10	10	10	10	10
DeviGain*	-	-	-	-	10	10
Lysine HCL	2.4	5.2	5.3	5.3	2.7	1.2
DL methionine	0.6	1.4	1.1	1.1	0.8	-
L threonine	-	1.8	1.7	1.7	0.8	-
Tryptophan	-	0.2	0.2	-	-	-
L valine		1.0			1.0	
Isoleucine		0.5			0.5	
Limestone	13.0	12.3	12.4	12.4	11.1	12.5
Mono DCP	3.5	5.7	4.4	4.4	10.5	4.8
Salt	6.3	4.4	4.3	4.3	6.2	6.6
Min/vits	3.0	3.0	3.0	3.0	3.0	3.0

*DeviGain (Devenish Nutrition) – amino acids glycated onto sugars

TABLE 4. INGREDIENT COMPOSITION OF EXPERIMENTAL DIETS USED IN "LOWERING DIETARY CRUDE PROTEIN IN FINISHING DIETS – THE EFFECT ON AMMONIA, ODOUR AND SLURRY PRODUCTION"

Crude Protein, %	18	15	13
Ingredient, g/kg			
Barley	210	275	250
Wheat	263	344	447
Maize	175	155	155
Maize DDGS	30	-	-
Pollard	75	50	50
Rapeseed ext	50	50	50
Hipro soybean	164	80	-
Soya oil	10	10	12
DeviGain*	-	10	10
Lysine	3.3	5.0	5.0
Methionine	0.4	1.0	0.3
Threonine	0.9	1.7	1.4
Tryptophan	-	0.3	0.2
Limestone	8.8	9.1	9.4
Mono DCP	2.1	2.8	3.5
Salt	4.4	3.3	3.3
Mins/vits	3.0	3.0	3.0

*DeviGain (Devenish Nutrition) – amino acids glycated onto sugars

TABLE 5. INGREDIENT COMPOSITION OF EXPERIMENTAL DIETS USED IN "LOW PROTEIN DIETS IN LATE FINISHING: PERFORMANCE AND EXCRETION"

Crude Protein, %	18	15	13
Ingredient, g/kg			
Barley	210	275	250
Wheat	263	344	447
Maize	175	155	155
Maize DDGS	30		
Pollard	75	50	50
Rapeseed ext	50	50	50
Hipro soybean	164	80	-
Soya oil	10	10	12
DeviGain*	-	10	10
Lysine	3.3	5.0	5.0
Methionine	0.4	1.7	1.1
Threonine	0.9	1.7	1.4
Tryptophan	-	0.3	0.2
Limestone	8.8	9.1	9.4
Mono DCP	2.1	2.8	3.5
Salt	4.4	3.3	3.3
Mins/vits	3.0	3.0	3.0

*DeviGain (Devenish Nutrition) – amino acids glycated onto sugars

TABLE 6. INGREDIENT COMPOSITION OF EXPERIMENTAL DIETS USED IN "DIETARY CRUDE PROTEIN AND LYSINE LEVELS FOR FINISHING PIGS"

Crude Protein, %	15	13 (Standard lysine)	13 (low lysine)
Ingredient, g/kg			
Barley	275	236	250
Wheat	344	438	447
Maize	155	155	155
Pollard	50	50	50
Rapeseed ext	50	50	50
Hipro soybean	80	24	-
Soya oil	10	10	12
DeviGain*	10	10	10
Lysine	5.0	4.9	4.7
Methionine	1.7	0.6	0.3
Threonine	1.7	1.5	1.4
Tryptophan	0.3	0.3	0.2
Limestone	9.1	9.3	9.4
Mono DCP	2.8	3.3	3.5
Salt	3.3	3.3	3.3
Mins/vits	3.0	3.0	3.0

*DeviGain (Devenish Nutrition) – asmino acids glycated onto sugars

TABLE 7. INGREDIENT COMPOSITION OF EXPERIMENTAL DIETS USED IN "EFFECT OF NUTRITION ON PIG PEN ODOUR"

	ODOUR 1	ODOUR 2	ODOUR 3	ODOUR 4	ODOUR 5	ODOUR 6
	High fibre (indigestible) + Fat (13.8 DE)	High fibre (indigestible) - Fat (13.3 DE)	High starch/Low fibre – Fat (13.8 DE)	High starch/Low fibre + Fat (14.3 DE)	High fibre (digestible) + Fat (13.8 DE)	High fibre (digestible) - Fat (13.45 DE)
Ingredient, g/kg						
Barley	193	193	400	400	98	112
Wheat	350	350	394	394	450	450
Maize	61	81	5	5	105	105
Maize DDGS	100	100	-	-	-	-
Pollard	100	100	50	50	-	-
Sugar beet pulp	-	-	-	-	100	100
Rapeseed ext	100	100	-	-	-	-
Hipro soybean	-	-	114	114	134	134
Soya hulls	43	43	-	-	67	67
Soya oil	25	5	5	25	19	5
DeviGain*	10	10	10	10	10	10
Lysine	3.8	3.8	3.0	3.0	2.3	2.3
Methionine	-	-	0.4	0.4	0.5	0.5
Threonine	0.4	0.4	0.7	0.7	0.3	0.3
Limestone	8.3	8.3	8.7	8.7	6.1	6.1
Mono DCP	-	-	2.2	2.2	1.1	1.1
Salt	3.0	3.0	3.8	3.8	3.9	3.9
Mins/vits	3.0	3.0	3.0	3.0	3.0	3.0

*DeviGain (Devenish Nutrition) – amino acids glycated onto sugars

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