Replacement of soya bean meal with peas and faba beans in growing / finishing pig diets: effect on performance, carcass composition and nutrient excretion.

G. A. White [1*], L. A. Smith [2], J. G. M. Houdijk [2], D. Homer [3], I. Kyriazakis [4] and J. Wiseman[1]

[1] *Division of Animal Sciences, School of Biosciences, Sutton Bonington Campus, University of Nottingham, Loughborough, Leicestershire, LE12 5RD, UK*

[2] *SRUC, West Mains Road, Edinburgh, Midlothian, EH9 3JG, UK*

[3] *BPEX, A Division of the Agriculture and Horticulture Development Board, Kenilworth, Warwickshire, CV8 2TL, UK*

[4] *School of Agriculture, Food and Rural Development, Newcastle University, Newcastle upon Tyne, NE1 7RU, UK*

* Corresponding author: Gavin White, gavin.white@nottingham.ac.uk

Abbreviations: CAM, coefficient of apparent metabolisability; CTTAD, coefficient of total tract apparent digestibility; DLWG, daily live weight gain; FCR, feed conversion ratio; SBM, soya bean meal

Abstract

There is now an increasing debate about the viability of using temperate-grown legumes in pig diets as a potential replacement for imported soya bean meal (SBM): this is due to food security, sustainability and environmental concerns. Two trials were designed to examine nitrogen (N) retention, growth performance and carcass quality of grower and finisher pigs when fed nutritionally-balanced SBM-free diets formulated to contain peas or faba beans at 300g/kg, compared to an SBM-containing, pulse-free control diet. Trial 1 evaluated N digestibility/retention in four iso-energetic diets, comparing the SBM control with one diet formulated with peas and two with faba bean cultivars; a tannin-containing and a tannin-free variety. This trial employed a four by four Latin Square Design with four male pigs housed in metabolism crates, fed twice daily at 0.9 of assumed *ad-libitum* intake over four time periods during grower (30-55kg) and finisher (55-95kg) phases. Quantitative faecal and urine collection allowed determination of N coefficient of total tract apparent digestibility, coefficient of apparent metabolisability, and N balance. Results revealed that dietary treatment did not affect these N parameters ($P>0.05$) during either the grower or finisher phase. Trial 2 evaluated growth performance (feed intake, daily live weight gain and feed conversion ratio) and carcass quality parameters. Five diets (based on SBM, peas and one of three faba bean cultivars) balanced for standard ileal digestible amino acids and net energy were each fed to eight replicates of individually-housed entire male pigs over the same growth phases as Trial 1. The inclusion of three faba bean varieties allowed comparison of animal responses between tannin/tannin-free and spring vs. winter bean cultivars. At ~95kg, pigs were slaughtered and a comprehensive range of carcass measurements undertaken. Samples of shoulder backfat were also taken at slaughter to determine skatole and indole concentrations. As with N balance, feeding treatment did not affect performance data. Carcass parameters revealed pigs fed the pea-based diet had a greater dressing percentage than those animals on faba bean-based diets. Pigs fed the SBM or pea-based diets also had greater lean meat percentages than those on faba-bean diets. Mean skatole concentrations for all pigs were below the accepted maximum threshold level of 0.2µg/g. In conclusion, it is suggested that peas and faba beans can be successfully fed in balanced pig diets throughout the grower/finisher periods as alternatives to SBM.

Keywords

Pigs, legumes, carcass, nitrogen balance, performance, soya bean meal

1. Introduction

In order to remain competitive in the global market, the pig sector must seek sustainable and viable solutions to the sourcing and level of dietary energy and nutrient inputs, whilst maintaining an acceptable level of output and animal performance. In temperate environments, there are increasing concerns surrounding the reliance by the pig industry on the importation of significant tonnages of soya bean meal (SBM). These concerns reflect wider debates surrounding resource use and sustainability in agricultural production (Leinonen et al., 2012; Leinonen et al., 2013). The implementation of regulations surrounding the development of 'Nitrate Vulnerable Zones' (NVZs) and their recent revision (DEFRA, 2013) provide clear evidence of how environmental legislation is impacting upon temperate pig production systems. In addition to the environmental aspects, debates about sustainability and higher feed prices mean that the pig feed industry is beginning to question its reliance on imported SBM.

Whilst SBM is a reliable source of high quality protein (Jezierny et al., 2010), the environmental impact of its sourcing, along with future price uncertainty, has led to increasing discussion about the use of protein alternatives in pig diets. Of particular interest are peas (*Pisum sativum*) and faba beans (*Vicia faba*) owing to the considerably reduced environmental concerns of growing these in temperate environments, due to their nitrogen-fixing ability (Crépon, 2006), compared to other protein crops such as rapeseed. The cultivation of these legumes in rotation systems reduces the reliance and energy expenditure associated with the use of substantial inputs of nitrogenous fertiliser. Additionally, when used to replace SBM in pig and poultry diets, peas and beans have been shown to have further environmental benefits including reduced acidification potential of pig and poultry production (Topp et al., 2012; Leinonen et al., 2013). Literature examining the nutritional value of peas and faba beans in pig diets have frequently reported equivocal conclusions (Fowler and Livingstone, 1977; Mateos and Puchal, 1980; Gatel, 1994; Castell et al., 1996) . Given the improvement in modern pig genotypes and the current environmental concerns highlighted above, it would seem particularly timely to revisit this issue, particularly in view of the recent move to use standardised ileal amino acid digestibility as the basis for diet formulation.

If there is to be an increased use of temperate-grown legumes, then the pig industry needs to be convinced that there will be no detrimental impacts on growth performance or carcass / meat quality arising from the inclusion of these raw materials in pig diets, when compared with more conventional diets based on imported SBM. Confidence in the use of peas and faba beans in non-ruminant diets has not been strong, partly due to concerns surrounding the number of different cultivars available, irregularity of supply, high costs and the presence of anti-nutritional factors; trypsin inhibitor activity in peas and condensed tannin content in faba beans (Jezierny et al., 2010; Masey O'Neill et al., 2012).

Recent dose-response studies have shown that peas and faba beans can completely replace SBM without penalizing growth performance and commercially obtained carcass characteristics, when separately tested in growing and finishing pigs (Smith et al., 2013). The aim of the current study was to extend this work by investigating the potential of using a greater range of faba bean cultivars as viable and sustainable alternatives to SBM in grower/finisher pig diets. In addition, a more comprehensive range of slaughter/carcass parameters were undertaken to further examine the effect of these legumes on carcass quality. The hypothesis tested was that these legumes could be included in balanced grower and finisher pig diets to replace completely SBM, with no detrimental effects on animal performance, nitrogen digestibility or carcass / meat quality parameters. The inclusion of peas and different faba bean varieties allowed a range of factors to be evaluated within the bounds of this hypothesis, including legume type (pea vs. faba bean), bean tannin content (tannin-containing vs. tannin-free) and season (spring-sown vs. winter-sown beans).

2. Materials and Methods

2.1. Diets

All animal protocols and procedures were conducted under both National and Institutional guidelines as approved in advance by the Ethical Review Committee of the School of Biosciences of the University of Nottingham, UK. Two trials were conducted; Trial 1 assessed nitrogen (N) digestibility/retention and Trial 2 evaluated growth performance and carcass quality in growing / finishing pigs when fed peas or faba beans as an alternative protein source to SBM in nutritionally balanced pelleted diets. Five dietary treatments were formulated for the grower phase; one control diet containing 140g SBM /kg of and four test diets each containing 300g home-grown legumes/kg with the legumes being white-flowered peas; cultivar ‘Prophet’, spring coloured-flowered faba beans ‘Fuego’, spring white-flowered faba beans ‘Tattoo’ or winter coloured-flowered faba beans ‘Wizard’. The different varieties of faba beans were expected to have different effects, especially in relation to their anti-nutritional properties. Laboratory analyses of the specific varieties of legumes used in the trials (including trypsin inhibitor activity and tannin content), have been reported elsewhere (Masey O'Neill et al., 2012). The white flowered faba bean cultivar 'Tattoo' was virtually tannin free. A second set of five diets were formulated containing either 120g Hipro SBM/kg or 300g of the four other legumes/kg for the finisher phase. The diet formulations were based on BSAS (2003) recommendations for nutrient and energy requirements, in the same way as used in the preceding dose-response studies (Smith et al. (2013). All dietary treatments were iso-energetic and were nutritionally balanced for standardised ileal digestible lysine, methionine, threonine and tryptophan through the use of pure amino acids. Dietary formulations and nutritional specification of the grower and finisher diets are shown in Table 1.

2.2. Trial 1

A four by four Latin Square design was employed using four entire male pigs (commercial white hybrid) over four collection periods to evaluate dietary treatments during the grower phase (from 30 - 55kg), and a second Latin Square with a new batch of pigs employed to evaluate dietary treatments over the finisher phase (55 - 95kg). Resource availability (number of metabolism crates) and experimental design (four by four Latin Square) meant that evaluation in the balance study was restricted to four diets; SBM, Prophet (peas), Fuego and Tattoo (faba beans) in each of the growth phases. The contrast between the latter two cultivars allowed for the comparison between a white and a coloured faba bean variety respectively. Each collection period consisted of an initial acclimatisation period of six days on the experimental diets, with pigs housed individually in holding pens. Animals were fed twice daily at 0.9 assumed *ad-libitum* intake, and the diets were mixed with water in the ratio 1:2. Fresh water was available *ad-libitum*. Pigs were then transferred to metabolism crates and the dye indigo carmine added (5g/kg diet) to the evening meal on the day following transfer. Quantitative faecal collection commenced on appearance of the dye in the faeces the following day, bulked for each pig over the collection period and was stored at -20°C pending laboratory analysis. At 0830 h that same day, quantitative urine collection commenced into vessels containing 25ml of 50% sulphuric acid to avoid evaporative losses. Daily urine output was assessed for pH, weighed and a sub-sample (1% by weight) collected and stored at -20°C pending nitrogen analysis. Indigo carmine was again added to the evening meal of the sixth day, with collection of urine finishing the following morning at 0830 h and quantitative faecal collection ceasing on reappearance of the dye on the following day. The use of a marker dye allowed variable rates of passage of digesta between individual animals to be accounted for. As such, by using this approach, faecal collection was related directly to 10 meals and urine collection related to five days. At the end of each collection period, animals were weighed, allocated to a new experimental diet with the amounts offered based on live weight and placed back in holding pens. Thus, over the duration of the study, each pig was fed each of the four diets and was transferred between holding pen and metabolism crate a total of four times.

Following completion of the metabolism study, faecal samples were thawed, homogenised and a sub-sample was frozen and dried to a constant weight to allow faecal dry matter (DM) to be determined. Diet, urine and faecal samples were analysed for nitrogen content, using the Dumas method. Urine samples were thawed, mixed and a 100µl sample pipetted into N-free potato starch before being analysed in triplicate for nitrogen. Subsequently, calculations of Coefficient of Total Tract Apparent Nitrogen Digestibility (CTTAD), Coefficient of Apparent Nitrogen Metabolisability (CAM) values and absolute N retention (g/day) were undertaken.

2.3. Trial 2

An additional dietary treatment (faba beans, var. 'Wizard', a winter-grown variety) was incorporated into Trial 2. Accordingly, five grower and five finisher dietary treatments were evaluated; SBM, Prophet, Fuego, Tattoo and Wizard. Each grower treatment was fed to eight replicates of individually housed commercial hybrid entire male pigs (initial weight ~30kg). Animals were transferred onto finisher treatments at 55kg and the trial continued until animals weighed ~95kg. Grower pigs were transferred onto the same legume-based diets for the finisher period (thus for example pigs fed the SBM diet during the grower phase were transferred to the SBM diet for the finisher phase). Diets were available on an *ad-libitum* basis, from a weighed amount of feed so that any spillages or feed refused could be weighed and feed intake (FI) for each animal calculated. Fresh water was available *ad-libitum*. Pigs were weighed on a weekly basis and weekly feed intake data were obtained throughout the period of the study. Performance calculations were conducted for grower (30-55kg) and finisher (55-95kg) phases of the study.

At approximately 95kg live weight, animals were transferred to the University of Nottingham experimental EU-licensed abattoir without a pre-slaughter starvation period and were slaughtered by electrical stunning followed by exsanguination. The use of an on-site abattoir allowed for more detailed and comprehensive assessment of carcass parameters than would be the case in a commercial abattoir. The whole carcass was scalded and dehaired. Both small and large intestines were carefully excised immediately following slaughter and weighed both with and without digesta contents. Carcass measurements of pH (to assess any evidence of Pale Soft Exudative (PSE) meat), temperature of *L. dorsi* and backfat depth at P2 site 'hot P2' (Introscope Optical Probe; SFK, Kolding, Denmark) were conducted on the left side at 45 minutes post slaughter. Carcasses were then split and stored at 4°C for 24hrs. A number of detailed carcass measurements were subsequently undertaken using a steel ruler and digimatic caliper 500 series (Mitutoyo, Japan). These measurements included loin muscle area and backfat thickness values, measured at a position level with the head of the last rib at 45mm (P1), 65mm (P2) and 80mm (P3) from the dorsal mid-line respectively, and subcutaneous fat depth at a position level with the top of the maximum height of *L. dorsi* (termed 'K'). Lean meat percentage was calculated from the industry-accepted equation based on P2 and cold carcass weight values (equation given in Table 4). A sample of shoulder backfat (~100mm x 50mm) was also taken from each animal at slaughter for indole and skatole analyses using the Likens-Nickersin method (Annor-Frempong et al., 1997) to assess the possible effect of legumes on concentrations of these metabolites in pig meat, which contribute to 'boar taint'. Finally muscle pH was determined.

2.4. Statistical analysis

Daily live weight gain (DLWG) was calculated as the linear slope of the response of live weight gain against time, in accordance with Van Lunen and Cole (1998). Solving the linear regression allowed an estimate of the actual day an animal weighed 30kg and reached 55kg (for the grower phase) which allowed a measurement of the precise amount of feed to grow over this live weight range and hence feed conversion ratio (FCR) to be determined. Data were subjected to analyses of variance (ANOVA) using a fully randomised design Genstat v13 (VSN International Ltd, Hemel Hempstead, UK) with dietary legume as the main factor. The effect of period was included as a factor in the analysis of trial 1, to account for the experimental model (Latin Square Design). Performance and carcass data in trial 2 were analysed with a set of orthogonal contrast statements to find effects of SBM vs. pulse, legume type (pea vs. faba bean), bean tannin content (high vs. low) and season (spring sown vs. winter sown beans). For the carcass measurements, cold carcass weight was initially employed as a covariate in the model but, as it was not significant, it was excluded from the final model used. Similarly, indole and skatole data were originally analysed with maximum shoulder fat depth as a covariate but, again as this variable was not significant, it was excluded from the model. Furthermore, indole and skatole data were log transformed before analysis in view of the non-normal distribution of the raw dataset. Both log transformed data and back-transformed means are reported.

3. Results

3.1. Trial 1

Dietary effects on mean CTTAD and CAM nitrogen values for the grower and finisher phases are shown in Table 2, along with N balance data over the two growth phases. There was no significant dietary effect on CTTAD or CAM of dietary N for either the grower or finisher phases (P >0.05). Regarding N retention; a significant period effect was evident with retention generally increasing over time (P <0.001), but there was no effect of diet (P >0.05). Urine pH values are also shown in Table 2; mean values were all below pH 4.0, indicating evaporative N losses during collection were unlikely. There was no treatment effect on urine pH during the grower phase although there was a significant effect of dietary treatment during the finisher phase, with pigs on the SBM diet exhibiting the least acidic urine. No effect of diet was found for total volume of urine produced in either phase.

3.2. Trial 2

Mean performance data (FI, DLWG and FCR) over the grower and finisher periods are shown in Table 3. Grower pigs fed ‘Wizard’ exhibited the greatest DLWG and animals on the SBM diet the smallest (P=0.065). Pigs fed the four pulse-based diets had significantly greater DLWG than pigs on the SBM diet (P = 0.027). There were no effects of dietary treatment on FI and FCR

Results of intestinal and carcass measurements are shown in Table 4. There was no significant effect of diet on digesta mass or empty intestinal weight in either the small or large intestine although there was a trend (P = 0.059) for pigs fed high tannin faba beans to have a greater empty large intestine weight than pigs fed the low tannin faba bean diet. As it was not possible to slaughter all animals exactly at 95kg, mean live weights at slaughter ranged from 94kg to 100kg and associated cold carcass weights (CCW) from ~68kg to 72kg. No significant treatment effects were found for hot P2 depth, carcass length, carcass temperatures (at 45min and 24hr post-slaughter) or carcass pH values at 24hr post-slaughter. An SBM vs. pulse effect was observed for carcass pH at 45 min post-slaughter with SBM pigs having a lower (more acidic) pH. There was no overall effect of diet on dressing percentage but pigs fed peas had a greater dressing percentage than pigs fed faba beans (P = 0.044). An overall dietary effect was observed for lean meat percentage (P = 0.036) with a significant SBM vs. pulse effect (P = 0.030). A significant effect of diet was also observed for a specific non-commercial fat depth measure ‘K’ (representing subcutaneous fat depth at a position level with the top of the maximum height of *L. dorsi*). Log-transformed indole and skatole data showed no significant dietary treatment effects. Back-transformed mean data are also included in Table 4, with overall back-transformed mean values for indole and skatole concentrations of 0.023µg/g and 0.055µg/g, respectively.

Mean faecal DM values from grower and finisher periods for both trials are shown in Table 5. Although animals in trial 1 exhibited greater absolute DM values across all dietary treatments than those in trial 2, no significant dietary effect was observed in either trial over the grower or finisher periods.

4. Discussion

The objective of the current study was to evaluate the potential of using peas and faba beans as a replacement for SBM in grower/finisher pig diets. The lack of significant differences observed between the SBM diet and experimental legume diets in terms of CTTAD and CAM nitrogen values were expected, as diets were balanced for net energy and, perhaps more importantly, for lysine, methionine, threonine and tryptophan. The urine of pigs fed the SBM diet was generally less acidic than that of their pea and faba bean-fed counterparts. For the finisher phase, urine pH was significantly less acidic which indicates that water intake was greater in these animals (although water intake was not measured in the current study), leading to an increased volume of urine produced. Although the basis of this effect on final urinary pH remains unclear, this is supported by the fact that finisher pigs fed the SBM diet voided a greater amount of urine over the collection periods than pigs on the other dietary treatments (Table 2). The lack of differences in faecal dry matter content is a useful observation, given the suggestion that diets high in legumes can result in diarrhoea/loose faeces in pigs (Jezierny et al., 2010) . The fact that for both trials, and over both the grower and finisher phases, faecal DM values were not significantly different between treatments, supports the view that accurately formulated diets based on peas and faba beans do not result in looser faeces (Smith et al., 2013). Although faecal DM values were greater across all treatments in Trial 1, compared with Trial 2, this is probably due to differences in feeding levels between the two studies (Trial 1; restricted vs. Trial 2; *ad-libitum* feeding).

The N balance data revealed an increase in daily N retention over time for both growth phases. This period effect would be expected, due to increased deposition of lean tissue, with a greater N requirement, reflected in higher retention values over time. The lack of any dietary effect on N retention indicates that using peas and faba beans to completely replace SBM in nutritionally balanced grower/finisher pig diets does not negatively influence N balance. The current study values are generally in agreement with reported balance values elsewhere (Reynolds and O'Doherty, 2006) and provide important information with regard to N retention in grower/finisher pigs when fed balanced diets containing significant proportions of legumes. The data indicate that feeding treatments did not affect the route and amount of N excretion as there were no dietary effects observed for either faecal or urinary N output or content (Table 2). This supports the view that using peas and faba beans to replace SBM in nutritionally balanced diets does not affect the contribution of manure to pig production eutrophication potential.

The performance data indicate that grower and finisher pigs are able to tolerate peas and faba beans in balanced diets at an inclusion rate of 300g/kg. These findings are in agreement with other studies evaluating legume inclusion in pig diets (Pearson and Smith, 1989; Stein et al., 2004; Smith et al., 2013). In the current study, grower pigs fed the experimental legumes had significantly greater weight gain than those fed SBM. In general, there appears to be some uncertainty with regards to a recommended upper limit for dietary inclusion of peas and faba beans in pig diets. Previous industry advice has suggested a maximum inclusion rate of 150g (grower) and 200g (finisher) faba beans/kg in balanced pig diets (Mavromichalis, 2012). Based on the results reported here and elsewhere (Smith et al., 2013), those inclusion levels could be increased, as the evidence from the current studies indicate that grower and finisher pigs are able to tolerate a greater rate of inclusion of peas or faba beans (300g/kg), provided that diets are nutritionally balanced. Indeed, peas have been incorporated in grower pig diets at up to 660g/kg with no negative affect on performance (Stein et al., 2006), suggesting that maximum dietary inclusion level should be based around economic evaluations, rather than any biological restrictions.

The experimental design for the growth study allowed animal performance to be directly compared when pigs were fed tannin-containing faba bean varieties ‘Fuego’ and ‘Wizard’ against a tannin-free cultivar ‘Tattoo’. Although there have been a number of nutritional studies with pigs examining the use of faba beans (with a low or high tannin content), it is acknowledged that trying to quantify the precise tannin effect from these is somewhat difficult (Crépon et al., 2010). The results of the current study revealed no association between animal performance and tannin content in the faba beans evaluated. This agrees with recent observations that faba bean tannins may not affect standardized ileal amino acid digestibility in broilers (Masey-O’Neill et al., 2012). Thus, (tannin-containing) faba beans could be successfully incorporated at 300g/kg in grower/finisher pig diets. This finding alone should be encouraging to end users, particularly when considering the perceived negative effects of tannins when formulating legumes in pig diets. Although only single batches of both SBM and pulses were evaluated in the current study, the similar performance between pigs fed the peas and faba bean diets strongly indicate that end users could consider using these temperate-grown pulses as potential alternatives to SBM, irrespective of legume type, tannin content and sowing season.

The carcass data revealed there was no evidence to indicate that digesta mass was influenced by dietary treatment, in either the small or large intestines although pigs fed pulses generally exhibited heavier empty large intestinal weights, suggesting an increased capacity for hindgut fermentation. Measurements of carcass pH at 45 min and at 24hr post slaughter allowed for the assessment of possible evidence of PSE meat. The lack of any visual evidence of PSE in any of the carcasses was not unexpected, given that all carcass pH values at 45 min were above 6, a lower threshold for increased PSE risk (Garrido et al., 1994).

There was a general lack of a dietary effect of the experimental legumes on the range of slaughter/carcass parameters assessed in the current studies. No overall difference was observed in terms of dressing percentage comparing SBM with the experimental pulse diets butdressing percentage was significantly greater for pigs on the pea diet, compared to faba beans. In the current studies, a dietary effect on lean meat percentage was found, although values for the pea diet were equivalent to that observed in pigs fed the SBM diet, and the overall coefficient of variation across all groups was only 0.5%. The general lack of effect on carcass parameters is in agreement with similar work comparing SBM with peas/faba beans (at ~300g/kg) in similar weight pigs (Stein et al., 2006; Smith et al., 2013), but also heavier pigs, slaughtered at 127kg (Prandini et al., 2011). At even heavier live weights (~158kg), the latter authors reported that pigs fed faba beans actually exhibited better carcass characteristics (greater carcass weight and increased loin thickness) than control pigs fed an SBM diet. The only significant effect of diet on carcass fat depth was for the non-commercial fat measurement ‘K’. Although this measurement is not used in assessing calculated total lean, it may support the view that total fat levels are reduced.

The issue of ‘boar taint’ in meat from entire male pigs is believed to be caused primarily by levels of skatole and androstenone, with contributions from other compounds including indole (Zamaratskaia and Squires, 2009). The production of skatole arises from the microbial degradation of tryptophan within the hind gut of the pig. Although there have been suggestions that feeding peas to pigs can result in increased backfat skatole deposition (Madsen et al., 1990; Lundström et al., 1994), more recent knowledge suggests that skatole levels are determined by a range of genetic, hormonal, environmental and nutritional factors (Zamaratskaia and Squires, 2009). Trial values for skatole in the current study were well below the currently agreed threshold level of 0.20-0.25µg/g where risks of boar taint are increased (Lundstrom et al., 2009), and the absence of a dietary treatment effect is consistent with other studies (O'Doherty and Keady, 2000; Smith et al., 2013).

5. Conclusion

The current trials revealed no difference in terms of growth performance, N balance and carcass quality results for pigs fed SBM or peas/faba bean diets. The lack of negative effects on animal performance and on carcass lean and fat measurements reported in the current study indicate that these legumes can be considered as viable alternative protein sources to SBM in nutritionally balanced grower and finisher pig diets.

Acknowledgements

Technical input from the Bio Support Unit (University of Nottingham) is gratefully acknowledged. The authors would like to thank Fran Whittington (University of Bristol, UK) for skatole/indole analyses and Jim Craigon (University of Nottingham) for statistical advice. Feeds were manufactured by Target Feeds, Whitchurch, Shropshire, UK. This research was carried out as part of the ‘Green Pig’ project, and was financially supported by BOCM Pauls (Ipswich, UK), BPEX, (Kenilworth, UK), Evonik Industries (Essen, Germany), Harbro (Turriff, UK), MPP (Burton on Trent, UK), PGRO (Peterborough, UK), Premier Nutrition (Rugeley, UK), QMS (Edinburgh, UK), Soil Association (Bristol, UK) and UNIP (Paris, France) with match funding from Defra, through the Sustainable Livestock

Production LINK programme. SRUC receives support from Scottish Government (RESAS).

References

Annor-Frempong, I.E., Nute, G.R., Whittington, F.W., Wood, J.D., 1997. The problem of taint in pork .2. The influence of skatole, androstenone and indole, presented individually and in combination in a model lipid base, on odour perception. Meat Science 47, 49-61.

Castell, A.G., Guenter, W., Igbasan, F.A., 1996. Nutritive value of peas for nonruminant diets. Animal Feed Science and Technology 60, 209-227.

Crépon, K., 2006. Nutritional values of legumes (pea and faba bean) and economics of their use., Recent Advances in Animal Nutrition, Nottingham University Press, Nottingham, UK, pp. 332-366.

Crépon, K., Marget, P., Peyronnet, C., Carrouee, B., Arese, P., Duc, G., 2010. Nutritional value of faba bean (Vicia faba L.) seeds for feed and food. Field Crops Research 115, 329-339.

DEFRA, 2013. Nitrate Vulnerable Zones. Retrieved on 20 March 2013 from http://www.defra.gov.uk/food-farm/land-manage/nitrates-watercourses/nitrates

Fowler, V.R., Livingstone, R.M., 1977. Replacement of soya bean as protein concentrate in pig diets by field beans (Vicia-fabia) and field peas (Pisum-sativum). Animal Production 24, 138-138.

Garrido, M.D., Pedauye, J., Banon, S., Laencina, J., 1994. Objective assessment of pork quality. Meat Science 37, 411-420.

Gatel, F., 1994. Protein quality of legume seeds for non-ruminant animals - A literature review. Animal Feed Science and Technology 45, 317-348.

Jezierny, D., Mosenthin, R., Bauer, E., 2010. The use of grain legumes as a protein source in pig nutrition: A review. Animal Feed Science and Technology 157, 111-128.

Leinonen, I., Williams, A.G., Waller, A.H., Kyriazakis, I., 2013. Comparing the environmental impacts of alternative protein crops in poultry diets: The consequences of uncertainty. Agricultural Systems 121, 33-42.

Leinonen, I., Williams, A.G., Wiseman, J., Guy, J., Kyriazakis, I., 2012. Predicting the environmental impacts of chicken systems in the United Kingdom through a life cycle assessment: Broiler production systems. Poultry Science 91, 8-25.

Lundström, K., Malmfors, B., Stern, S., Rydhmer, L., Eliasson-Selling, L., Mortensen, A.B., Mortensen, H.P., 1994. Skatole levels in pigs selected for high lean tissue growth rate on different dietary protein levels. Livestock Production Science 38, 125-132.

Lundstrom, K., Matthews, K.R., Haugen, J.E., 2009. Pig meat quality from entire males. Animal 3, 1497-1507.

Madsen, A., Oesterballe, R., Mortensen, H.P., Bejerholm, C., Barton, P., 1990. Foderets indflytelse paa ravarekvaliteten hos slagtesvin, 1. Tapiokamel, skummetmaelkspulver, aerter, rapskager, rapsfro, halm, havre og nogen havre. Beretning fra Statens Husdyrbrugsforsoeg, 673.

Masey O'Neill, H.V., Rademacher, M., Mueller-Harvey, I., Stringano, E., Kightley, S., Wiseman, J., 2012. Standardised ileal digestibility of crude protein and amino acids of UK-grown peas and faba beans by broilers. Animal Feed Science and Technology 175, 158-167.

Mateos, G.G., Puchal, F., 1980. Faba beans as a protein source for growing-finishing pigs. Journal of Animal Science 51, 72-73.

Mavromichalis, I., 2012. Nutrition FAQ: Minor legumes., Pig Progress, p. 4.

O'Doherty, J.V., Keady, U., 2000. The nutritive value of extruded and raw peas for growing and finishing pigs. Animal Science 70, 265-274.

Pearson, G., Smith, W.C., 1989. Effect of inclusion rate of peas (Pisum sativum var Pania) in the diet on the performance of growing pigs. New Zealand Journal of Agricultural Research 32, 117-120.

Prandini, A., Sigolo, S., Morlacchini, M., Cerioli, C., Masoero, F., 2011. Pea (Pisum sativum) and faba bean (Vicia faba L.) seeds as protein sources in growing-finishing heavy pig diets: effect on growth performance, carcass characteristics and on fresh and seasoned Parma ham quality. Italian Journal of Animal Science 10, 176-183.

Reynolds, A.M., O'Doherty, J.V., 2006. The effect of amino acid restriction during the grower phase on compensatory growth, carcass composition and nitrogen utilisation in grower-finisher pigs. Livestock Science 104, 112-120.

Smith, L.A., Houdijk, J.G.M., Homer, D., Kyriazakis, I., 2013. Effects of dietary inclusion of pea and faba bean as a replacement for soybean meal on grower and finisher pig performance and carcass quality. Journal of Animal Science 91, 3733-3741.

Stein, H.H., Benzoni, G., Bohlke, R.A., Peters, D.N., 2004. Assessment of the feeding value of South Dakota-grown field peas (Pisum sativum L.) for growing pigs. Journal of Animal Science 82, 2568-2578.

Stein, H.H., Everts, A.K.R., Sweeter, K.K., Peters, D.N., Maddock, R.J., Wulf, D.M., Pedersen, C., 2006. The influence of dietary field peas (Pisum sativum L.) on pig performance, carcass quality, and the palatability of pork. Journal of Animal Science 84, 3110-3117.

Topp, C.F.E., Houdijk, J.G.M., Tarsitano, D., Tolkamp, B.J., Kyriazakis, I., 2012. Quantifying the environmental benefits of using home grown protein sources as alternatives to soyabean meal in pig production through lifecycle assessment., Advances in Animal Biosciences, p. 15.

Van Lunen, T.A., Cole, D.J.A., 1998. The effect of dietary energy concentration and lysine digestible energy ratio on growth performance and nitrogen deposition of young hybrid pigs. Animal Science 67, 117-129.

Zamaratskaia, G., Squires, E.J., 2009. Biochemical, nutritional and genetic effects on boar taint in entire male pigs. animal 3, 1508-1521.

Table 1 *Composition and nutritional specification of experimental diets (g/kg as-fed)*

	Grower Phase Diets					Finisher Phase Diets				
Item	SBM	Prophet	Fuego	Tattoo	Wizard	SBM	Prophet	Fuego	Tattoo	Wizard
Ingredients										
Hipro Soya bean meal	140					120				
Peas (var. Prophet)		300					300			
Faba beans (var. Fuego)			300					300		
Faba beans (var. Tattoo)				300					300	
Faba beans (var. Wizard)					300					300
Wheat	446	283	293	280	293	264	83	91	79	91
Barley	128	128	128	128	128	284	284	284	284	284
Molasses	30	30	30	30	30	30	30	30	30	30
Rapeseed meal	70	70	70	70	70	70	70	70	70	70
Wheat feed	150	150	150	150	150	200	200	200	200	200
Soya bean oil	11	11	3	16	3	10	10	3	15	3
Lysine	1.50	2.10	1.66	1.70	1.80	0.60	0.60	0.14	0.11	0.23
Methionine	0.06	0.65	0.70	0.80	0.72	-	0.40	0.37	0.42	0.38
Threonine	0.05	1.10	0.75	0.70	0.80	-	0.30	-	-	0.02
Tryptophan	-	0.20	0.14	0.05	0.14	-	-	-	-	-
Dicalcium phosphate	5.5	5.5	5.5	5.2	5.5	4.5	4.5	4.5	4.5	4.5
Limestone	11.6	12.2	11.7	11.9	11.7	11.3	11.5	11.1	11.1	11.1
Salt	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Vitamin/Mineral Premix[1]	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Nutritional Value										
Dietary Nitrogen (g/kg)	29.6	26.5	27.2	28.3	28.7	26.9	25.3	27.0	26.8	28.9
Energy values										
DE (MJ/kg)	13.6	13.6	13.6	13.6	13.6	13.2	13.2	13.2	13.2	13.2
NE (MJ/kg)	9.3	9.3	9.3	9.3	9.3	9.0	9.0	9.0	9.0	9.0
Ca	7.2	7.2	7.2	7.2	7.2	6.8	6.8	6.8	6.8	6.8
digP	2.5	2.5	2.5	2.5	2.5	2.4	2.4	2.4	2.5	2.4
NDF	135	147	154	152	154	160	172	179	177	179

Amino acids										
SID Lys	8.1	8.1	8.1	8.1	8.1	7.1	7.1	7.1	7.1	7.1
Total Lys	9.4	9.6	9.7	9.8	9.6	8.5	8.8	8.9	8.9	8.7
Met	2.4	2.4	2.4	2.4	2.4	2.3	2.1	2.1	2.1	2.1
M+C	5.2	4.6	4.7	4.9	4.7	4.9	4.3	4.4	4.5	4.4
Thr	5.3	5.3	5.3	5.3	5.2	5.0	4.6	4.7	4.7	4.6
Try	1.9	1.5	1.5	1.5	1.5	1.8	1.4	1.4	1.5	1.4
Iso	5.9	4.7	5.1	5.3	5.0	5.6	4.6	5.1	5.2	5.0
Leu	10.6	8.5	9.6	9.9	9.4	10.1	8.5	9.6	9.9	9.4
His	3.9	3.1	3.6	3.7	3.6	3.8	3.1	3.6	3.7	3.6
Val	6.9	5.6	6.1	6.4	6.0	6.6	5.7	6.2	6.5	6.1

[1]Provides the following quantities per kilogram of complete diet: retinol, 10,000 IU; cholecalciferol, 2000 IU; tocopherol, 50 mg; thiamine, 2 mg; riboflavin, 3 mg; pyridoxine, 2 mg; cyanocobalamin, 30 mg; menadione, 1 mg; nicotinic acid, 20 mg; pantothenic acid, 10 mg; Fe (as $FeSO_4H_2O$), 100 mg; Mn (as MnO), 50 mg; Cu (as $CuSO_4$), 20 mg; Zn (as ZnO), 100.6 mg; I [as $Ca(IO_3)_2$], 1 mg; Se (as $NaSeO_4$), 0.3mg.

Table 2 *Effect of soya bean meal (SBM), pea (Prophet) or faba bean (Fuego and Tattoo)-based diets on urine pH and volume, nitrogen balance, digestibility and retention in grower and finisher pigs[1] (Trial 1).*

	Grower phase (35-55kg)						Finisher phase (55-95kg)					
Item	SBM	Prophet	Fuego	Tattoo	sed	*P*	SBM	Prophet	Fuego	Tattoo	sed	*P*
Urine pH	2.7	2.4	2.4	2.7	0.18	0.104	3.4^{ab}	2.8^{c}	2.9^{c}	3.1^{ac}	0.20	0.013
Urine total volume (L)	14	11	15	14	3.9	0.785	15	12	14	14	3.5	0.734
Nitrogen balance												
N intake (g)	315	282	289	308	41.2	0.831	362	340	363	360	34.2	0.889
Faecal N output (g)	53	54	61	62	6.8	0.392	74	78	85	75	5.4	0.211
Urinary N output (g)	93	76	74	90	17.3	0.605	103	92	105	100	16.7	0.847
Faecal N content (g/kg)	10	11	11	12	0.9	0.393	10	11	11	11	1.3	0.914
Urinary N content (g/kg)	7	7	5	7	1.5	0.586	7	8	8	7	0.6	0.946
Nitrogen digestibility												
CTTAD[2]	0.83	0.81	0.79	0.79	0.025	0.264	0.80	0.77	0.76	0.79	0.021	0.416
CAM[3]	0.53	0.54	0.54	0.50	0.054	0.905	0.51	0.50	0.47	0.51	0.039	0.704
Nitrogen retained[4] (g/day)	34	31	31	31	5.7	0.923	37	34	35	37	5.0	0.897

[1] Experimental design was a four by four Latin Square (n = 4 pigs per growth phase)

[2] Coefficient of Total Tract Apparent Digestibility ((N intake – faecal N output) / N intake)

[3] Coefficient of Apparent Metabolisability ((N intake – faecal N output - urinary N output) / N intake)

[4] Based on quantitative faecal and urine collection over four time periods; each period involved collection over 10 meals (5 days)

$^{a-c}$ Values within a row with different superscripts differ significantly at $P<0.05$

Table 3 *Effect of soya bean meal (SBM), pea (Prophet) or faba bean (Fuego, Tattoo and Wizard)-based diets on performance parameters[1] of grower and finisher pigs (Trial 2).*

Item	Dietary treatment					sed	*P*				
	SBM	Prophet	Fuego	Tattoo	Wizard		Diet	SBM vs. pulse	Pea vs. faba bean[2]	High vs. low tannin[3]	Spring vs. winter sown[4]
Grower Phase (30-55kg)											
Feed Intake	48	48	46	46	47	1.8	0.838	0.482	0.371	0.825	0.824
Daily Live Weight Gain (kg/day)	0.92	0.95	0.99	0.96	1.02	0.035	0.065	0.027	0.190	0.156	0.464
Feed Conversion Ratio	1.92	1.91	1.86	1.85	1.87	0.074	0.834	0.481	0.367	0.821	0.827
Finisher Phase (55-95kg)											
Feed Intake	122	119	118	116	122	5.6	0.810	0.429	0.997	0.455	0.547
Daily Live Weight Gain (kg/day)	1.13	1.19	1.17	1.10	1.14	0.049	0.482	0.561	0.226	0.256	0.558
Feed Conversion Ratio	3.05	2.97	2.95	2.90	3.04	0.140	0.811	0.430	0.997	0.454	0.546

n = 8 pigs per dietary treatment in each growth phase

[1] Calculated by regression analysis over the specific growth period

[2] Prophet (*Pea*) vs. Fuego, Tattoo and Wizard (*Faba beans*)

[3] Fuego & Wizard (*High tannin*) vs. Tattoo (*Low tannin*)

[4] Fuego (*Spring sown*) vs. Wizard (*Winter Sown*)

Table 4 *Effect of soya bean meal (SBM), pea (Prophet) or faba bean (Fuego, Tattoo and Wizard)-based diets on slaughter parameters of finisher pigs (Trial 2).*

Item	Dietary treatment					sed	*P*				
	SBM	Prophet	Fuego	Tattoo	Wizard		Diet	SBM vs. pulse	Pea vs. faba bean[1]	High vs. low tannin[2]	Spring vs. winter sown[3]
Parameter at slaughter											
Live weight (kg)	94	98	98	100	98[b]	1.6	0.047	0.005	0.622	0.211	0.940
Intestinal weight (kg)											
S.I. – empty	1.9	2.2	2.0	2.1	2.0	0.13	0.300	0.320	0.102	0.276	0.895
L.I. – empty	1.6	1.6	1.8	1.6	1.9	0.13	0.122	0.277	0.145	0.059	0.452
S.I. digesta	1.8	1.9	1.9	2.0	2.0	0.29	0.931	0.474	0.916	0.677	0.720
L.I. digesta	2.0	1.9	2.5	2.2	2.6	0.44	0.372	0.385	0.123	0.295	0.951
Carcass parameters											
Temp (°C) at 45 min	40	38	39	39	39	1.0	0.218	0.088	0.103	0.664	0.933
pH at 45min	6.1	6.3	6.5	6.3	6.4	0.14	0.081	0.030	0.286	0.159	0.396
Hot P2 (mm) by probe	11	11	10	10	11	0.8	0.285	0.369	0.397	0.675	0.070
Shoulder backfat[4]											
Indole; µg/kg fat	1.3 (0.02)	1.3 (0.02)	1.4 (0.04)	1.2 (0.02)	1.5 (0.03)	0.11	0.524	0.729	0.475	0.122	0.777
Skatole; µg/kg fat	1.7 (0.07)	1.6 (0.04)	1.7 (0.06)	1.8 (0.06)	1.7 (0.06)	0.13	0.494	0.664	0.085	0.779	0.891
Parameter at 24hr post-slaughter											
Carcass parameters											
Carcass weight (kg)	68	72	71	72	71	1.2	0.018	0.003	0.352	0.141	0.842
Carcass length (mm)	813	814	831	823	819	8.0	0.186	0.182	0.117	0.727	0.165
Carcass temp (°C)	2.8	2.7	2.4	2.7	2.8	0.21	0.439	0.412	0.699	0.517	0.116
Carcass pH	5.5	5.4	5.5	5.4	5.5	0.06	0.405	0.684	0.269	0.113	0.825
Dressing %	72.3	73.8	72.0	72.5	72.4	0.86	0.296	0.535	0.044	0.665	0.686
Lean meat %[5]	62.8	62.8	62.4	62.6	62.5	0.16	0.036	0.030	0.058	0.221	0.315
L. dorsi (mm)											
Maximum height	89	92	92	93	92	2.3	0.561	0.104	0.917	0.637	0.996
Maximum width	55	60	59	57	56	2.3	0.278	0.153	0.193	0.932	0.241
Subcutaneous fat depth(mm)											
P1	8.8	8.5	8.1	8.3	8.6	0.64	0.782	0.340	0.770	0.902	0.407
P2	9.1	8.3	7.8	8.7	8.6	0.66	0.402	0.147	0.957	0.408	0.274

P3	10	9	8	8	9	0.66	0.212	0.064	0.402	0.440	0.285
K[6]	15.3	14.4	12.8	11.6	13.4	0.96	0.005	0.005	0.024	0.086	0.527

S.I. = small intestine, L.I. = large intestine.

[1] Prophet (*Pea*) vs. Fuego, Tattoo and Wizard (*Faba beans*)

[2] Fuego & Wizard (*High tannin*) vs. Tattoo (*Low tannin*)

[3] Fuego (*Spring sown*) vs. Wizard (*Winter sown*)

[4] Back-transformed mean values are shown in parentheses (ug/g fat)

[5] LM % = 66.5 - (0.95*P2) + (0.068*cold carcass weight) (Warriss, 2010)

[6] Subcutaneous fat depth at a position level with the top of the maximum height of *L. dorsi* (carcass suspended)

Table 5 *Effect of soya bean meal (SBM), pea (Prophet) or faba bean (Fuego, Tattoo and Wizard)-based diets on mean faecal dry matter (g/kg) of grower and finisher pigs (Trials 1 and 2)*

	Dietary treatment						
	SBM	Prophet	Fuego	Tattoo	Wizard	sed	*P*
Trial 1							
Grower phase (35-55kg)	312	332	324	332	-	21.4	0.769
Finisher phase (55-95kg)	299	317	317	315	-	19.6	0.756
Trial 2							
Grower phase (35-55kg)	264	259	262	263	265	12.3	0.990
Finisher phase (55-95kg)	261	278	270	272	279	7.6	0.179