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The effects of dietary fructo-oligosaccharide addition on boar taint compounds and performance in heavy slaughter weight boars and gilts

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Abstract

Increasing slaughter weight in finishing pigs may increase the risk of carcass taint from compounds such as skatole. An experiment was carried out to determine the effects of dietary inclusion of short chain fructo-oligosaccharide (scFOS), on performance, the levels of skatole in digesta, faeces and backfat in heavy slaughter weight boars and gilts. Pigs (n=112), with an initial bodyweight of 57 ± 1.15 kg. (mean $\pm$ SD), were allocated in a randomised complete block arrangement in four replicates over two time blocks. Pigs were allocated to one of two dietary treatments, Negative Control (NC) and Negative Control plus 2g/kg scFOS and separated by gender, boar and gilt to create a 2x2 factorial design. Pigs were housed in single sex pens of 6-8 pigs in controlled-environment, partially-slatted pens. The Basal NC diet was a commercial pelleted finisher diet (170.8 g/kg CP, 13.37 MJ/kg DE, 10.3 g/kg Lysine) fed ad-libitum. The scFOS preparation contained kestose, nystose and fructosyl nystose.

Abbreviations: B boar; CP crude protein; DE digestible energy; DFI daily feed intake; DLWG daily live weight gain; DLTG daily lean tissue growth; FCR feed conversion ratio; FOS fructo-oligosaccharides; G gilt; LWT liveweight; NC negative control; NSP non-starch polysaccharides, MJ/kg DE mega joule per kilogram; MLC Meat and Livestock Commission; scFOS short chain fructo-oligosaccharide; SBP sugar beet pulp

Pen feed intake was calculated weekly with pigs being weighed and backfat measurements taken every two-weeks to calculate daily live weight gain with back fat at the P2 position measured ultrasonically. Faecal samples were taken at each weighing, and colon content and backfat samples were taken at slaughter. Data were evaluated using analysis of variance. Boars were more efficient than gilts at this heavier weight range, but back fat thickness showed no difference between genders. Faecal indole concentration increased with age, but faecal skatole did not reflect this increase. A 2g/kg dietary inclusion of scFOS had no effect on performance and no consistent significant effect on skatole or indole concentrations in faeces or in the colon digesta at slaughter. However, scFOS did reduce ($P<0.009$) the carcass fat concentration of skatole thus reducing risk of carcass taint. This effect was more pronounced in the boars due to their higher fat skatole concentration. These results suggest a 2g/kg dietary inclusion of scFOS in finisher diets would be beneficial in reducing carcass taint but not in the reduction of malodorous faecal compounds.

Keywords: Non starch polysaccharide, pig, skatole, taint, boars, performance

1 Introduction

As dietary nutrient density requirement decreases with increasing age, the diet may oversupply the energy and protein needed for lean tissue growth in the later stages of fattening, resulting in reduced feed efficiency and poorer carcass grading. There is also increased risk of the microbial degradation of excess amino acids such as tryptophan to skatole and other indolic compounds which give undesirable odours and flavours (taint) in the carcass (Laue et al., 1997). The risk of such compounds is increased when pigs are taken to heavier weights. Part of this risk is derived from the development of androstenone production in entire males, but a significant part is related to dietary factors (Raab et al., 1997). The use of non-starch polysaccharides

(NSP) has been suggested to give a reduction in the production and absorption of skatole, although previous trials using NSP have produced conflicting results (Van Oeckel et al., 1998; Wiseman et al., 1999; Knarreborg et al., 2002). The use of fructo-oligosaccharides (FOS), has been shown to influence the microbial population and reduce skatole production in vitro (Xu et al., 2002), but this has yet to be proven consistently in vivo. Short chain FOS (scFOS) are compounds built up of fructose molecules with a glucose molecule. Short chain FOS are found in many fruit and vegetables, being most abundant in artichoke, chicory and members of the onion family (Campbell et al., 1997). They are resistant to acidic and enzymatic hydrolysis in the gastrointestinal tract (Cromwell, 2001), and thus act as a substrate for beneficial microflora in the proximal part of the colon.

The principal microflora affected favourably appear to be Bifidobacteria and some Lactobacilli. The growth of the Bifidobacteria is usually accompanied by a decrease in pH in the large intestine (Bornet et al., 2002). This decrease in pH is thought to change the gut environment and the microbial biota and shift the microbial metabolism of tryptophan away from skatole production and towards indole production (Xu et al., 2002, Li et al., 2009). The hypothesis of this study is that the inclusion of scFOS reduces the production of skatole and its storage in back fat in heavy weight slaughter boars and gilts, and hence the risk of boar taint in the meat products.

2 Materials and Methods

2.1 Pigs, experimental design and diets

A randomised complete block arrangement in four replicates over two time blocks was used to study the effect of scFOS and gender on skatole production and carcass taint in heavy finishing weight pigs. Pigs were allocated to one of two dietary treatments, Negative Control (NC) and Negative Control plus 2 g/kg scFOS (scFOS) and separated by gender, entire boar (B) and gilt (G) to create a 2x2 factorial design. The experiment was carried out at the University of Newcastle's pig research unit. A total of 112 Large White - Landrace cross pigs were taken from the University of Newcastle's commercial finishing herd, selecting equal numbers of boars and gilts at an average liveweight of 57kg±9.53 (mean ± standard deviation). Pigs were housed in single sex pens within single sex rooms. For replicates 1 and 2, eight pigs were reared per pen. In replicates 3 and 4, the number was reduced to six pigs per pen. The building was filled twice over time, giving a total of 4 pen replicates for each of the treatment combinations. Pens had partially slatted concrete floors with 22% slatted area. Room temperature was controlled initially at 19°C, and gradually reduced weekly to 14°C, by thermostatically controlled fan ventilation. Lighting was controlled automatically with 12 hours light, 12 hour dark. Pen size was 9.6m², providing a space allowance of 1.2m²/pig for the first two replicates, and 1.6m² for the subsequent two.

Pigs were fed using one single diet per treatment from 60kg to 130kg. The diets were fed ad libitum as a dry pellet. Diets were manufactured by a commercial

manufacturer (Top Grade Finisher pellets, FeedCo, Cocklane, Piercebridge, County Durham, DL2 3TJ), with identical basal formulation (Table 1) (170.8 g/kg crude protein, 10.3 g/kg lysine, 13.37 MJ digestible energy/kg) for both NC and NC+scFOS containing diet

The scFOS was sourced from SCA Nutec Ltd, Eastern Avenue, Watery Lane, Lichfield, UK. The addition of 2kg/tonne of scFOS, replacing 2 kg of the wheat in the basal NC diet was based on commercial recommendations from previous research. The scFOS product contained kestose, nystose and fructosyl nystose at a ratio of 370g/kg:530g/kg:100g/kg.

For replicates one and two, a feeder space allowance of 15cm/pig was provided. For replicates three and four a feeder space allowance of 10cm/pig. Trough space was reduced to reduce the apparent feed wastage visible in replicates one and two. Feed hoppers were topped up as required to maintain ad libitum access. Feed inputs were recorded and feed refusals weighed weekly, and additionally when any pigs were removed, to calculate mean daily feed intake per pig.

2.2 Experimental procedures and sampling

Pigs were allocated to balance pens for age and weight, with a start weight of approx 57kg. Pigs within each block were selected from a group born in the same week, and animals were individually ear tagged once allocated. Slaughter date was dependent on live weight, rather than a fixed age. Pigs were slaughtered in two stages

per pen, with the first when the average live weight of 50% of the pigs reached 130kg. If there was a large variation of live weight within a pen, the pigs were slaughtered before reaching a maximum of 135kg.

Pigs were individually weighed and ultrasonic back fat measurements taken at the P2 site using a Meritronics Livestock Grader (Meritronics Ltd, Faversham, Kent, ME13 0BT), at allocation, and then fortnightly until slaughter. At each weighing, spontaneously voided faecal samples were collected for skatole and indole analysis. Pigs were monitored daily for signs of ill health, and any illness or treatment was recorded.

Pigs were slaughtered at a local commercial abattoir, and normal commercial data (hot/cold carcass weight, P2, lean percentage), were recorded for individually identified animals. Animals were identified with an individual slap mark visible throughout the slaughter process. Approximately 100ml of digesta sample from both the proximal and distal colon were taken at slaughter and subsequently analysed for pH, skatole and indole concentration. Fat samples for skatole analysis (approximately 100g), were collected from between the 3rd and 4th vertebrae. Each carcass was assessed after evisceration and skin lesions quantified as per the MLC rind side damage scale (1-5 score of increasing severity, MLC, no date).

Estimated carcass lean percentage at different live weights was calculated by the following equation (MLC, 2006):

$$\text{Carcass lean (kg)} = (66.5 - (0.95 \times P_2\text{mm})) + (0.068 \times \text{carcass weight kg})$$

where carcass weight is (Whittemore and Kyriazakis 2006) :

$$\text{Carcass wt (kg)} = \text{live weight} \times \text{Killing Out percentage (\%)} \\ ((66 + (0.09 \times \text{liveweight}) + (0.012 \times \text{P}_2 \text{ back fat})) / 100)$$

Carcass protein deposition rate (g/day) was calculated as follows:

$$((\text{final cold weight}^a \times \text{lean content}^b \times \text{crude protein content}^c) \\ - (\text{initial live weight}^a \times 0.739 \times 155^d)) / \text{days}$$

^ainitial and final cold weight in kg, ^bestimated lean percentage from abattoir data, ^{cd} from Weatherup et al. (1998), crude protein in grams,

2.3 Analytical procedures

Proximate analysis of the diets was estimated by NIR (FeedCo, Cocklane, Piercebridge, County Durham, DL2 3TJ). Concentrations of skatole and indole in gut contents and faeces were measured by the method of Whittington et al. (2004). Skatole in carcass fat was measured by the method described in Annor-Frempong et al. (1997). pH was measured using a Hanna pH meter with glass electrode, using a method derived from Radcliffe et al. (1998), but using 1g digesta into 5ml deionised water and agitated until thoroughly mixed. Samples were left to separate for 15

minutes before the glass electrode was placed into top third of the supernatant and the pH measurement taken once the pH measure had stabilised.

2.4 Statistical analyses

Data on performance, lean tissue growth and carcass traits were subject to two-way analysis of variance using the General Linear Model program of Minitab (release 13.1), using gender, dietary treatment and their interaction as factors. The pen mean was the statistical unit of analysis.

The analysis of lean tissue growth rate and back fat levels by time was subject to Repeated Measures analysis of variance using Genstat software (Genwin32), with gender, dietary treatment and week plus their interactions as factors. Regression analyses of relationships between live weight, back fat measurement and estimated carcass lean were carried out using linear regression analysis (Minitab release 13.1). The individual pig was the statistical unit of analysis.

The concentrations of taint compounds in faeces, digesta and fat at slaughter were subject to two-way analysis of variance using the individual pig as the statistical unit, with gender, diet and their interaction as factors. Where data were skewed, log₁₀ transformation was used. Relationships between these data and individual slaughter live weight, slaughter back fat and digesta pH were also subject to linear regression analysis.

Differences among means with $P < 0.05$ were accepted as statistically significant with differences between means with $P = 0.05-0.1$ were accepted as representing tendencies to differences.

3 Results

3.1 Growth performance

Since start weights were balanced at allocation and pigs were selected for slaughter at a predetermined live weight (Table 2), there were no significant differences between treatment or gender in start and slaughter weight. Dietary treatment showed no effect on DLWG over the experimental period. There was no effect of scFOS on daily feed intake (DFI), but during the week 0-6 phase the scFOS showed an improved FCR compared with the control ($P = 0.036$). This was not repeated in the week 6-slaughter phase or for the overall experiment. The mean daily intake of the scFOS was not affected by gender with 5.7g/d for boars and 5.36g/d for gilts over the course of the experiment.

There was no significant gender by treatment interaction for any of the performance parameters measured. At week 6, when pigs reached the traditional slaughter weight of approximately 90 kg, the boars were heavier compared with the gilts ($P = 0.009$). Although DLWG was not different between gender over this first period ($P = 0.127$), boars showed higher DLWG from week 6 to slaughter ($P < 0.001$), and over the whole experiment ($P < 0.001$). Related to increased DLWG, boars also

showed a tendency of increased calculated daily lean tissue growth (DLTG), between allocation and week 6 ($P=0.051$), and a greater DLTG in the week 6 to slaughter ($P<0.001$), and the overall experimental period ($P<0.001$), when compared with gilts.

When data for live weight and back fat were plotted for the experimental period from week 2 to week 12 (see Figure 1), it was clear the live weight increase was associated with a linear increase in subcutaneous fat for the majority of the period, although there was an indication that gilts began to show greater increase in fat in the final stage.

3.2 Carcass data

Carcass data are presented in Table 3. There were no main effects of scFOS supplementation on start-to-slaughter pig days, killing out percentage, hot carcass weight, cold carcass weight or protein deposition rate. Back fat thickness recorded on-farm and at slaughter showed no effect of scFOS, which resulted in the lack of treatment effect on estimated carcass lean percentage. Back fat thickness recorded ultrasonically on the live animal prior to slaughter was lower than that measured by intrascope on the carcass at slaughter, but both measurements showed no significant effect of gender. This was supported by the lack of a gender effect on estimated lean percentage in the abattoir data. Rindside damage assessment showed no dietary treatment effect or treatment by gender interaction despite boars tending to exhibit greater damage post slaughter than gilts ($P=0.072$).

In the carcass parameters measured, the one significant interaction between scFOS and gender, the carcass back fat measurement measured at the abattoir (P=0.024), occurred because gilts fed the control diet were fatter at slaughter. When examining the performance data, these gilts were also the slowest growing and with the least efficient FCR.

An effect of gender was evident in the killing out percentage, hot carcass weight and cold carcass weight. The gilts exhibited an increased killing out percentage (P=0.006) and subsequently increased hot and cold carcass weight (P=0.005 and P=0.008 respectively). Boar allocation-to-slaughter pig days were lower compared with gilts (73 days compared with 85 days, respectively, P<0.001), indicating that boars were younger at slaughter. The calculated carcass protein deposition rate showed a gender effect (P=0.001) with boars gaining an increased 102.4/d of protein compared with the mean gilt deposition rate of 94.0g/d over the course of the experiment.

3.3 Indolic compounds

The data presented in Table 4 indicate that, in this instance, scFOS had limited and inconstant effect on both skatole and indole levels found in faecal and colon samples. A significant dietary treatment effect was observed for faecal skatole concentration at week 1 with scFOS treatment increasing faecal skatole concentration (P=0.030), (Table 4), and a tendency of increased proximal colon digesta indole

concentration ($P=0.094$). The proximal and distal colon digesta pH was also not affected by the scFOS treatment ($P=0.769$ and $P=0.601$ respectively).

There was no apparent gender by diet interaction for any of the indolic parameters measured (Table 5). Any gender specific effect on the indolic compounds was limited to skatole concentration of slaughter faecal samples ($P=0.040$). Mean boar faecal skatole concentration of $16.2\mu\text{g/g}$ was greater compared with the gilt faecal concentration of $12.5\mu\text{g/g}$. The boars also showed a lower digesta pH in the distal colon digesta ($P=0.015$) and a tendency of lower pH in the proximal colon digesta ($P=0.07$).

As presented in Table 5, the fat skatole and indole response to scFOS showed a varying response. The scFOS treatment reduced the fat skatole concentration to $0.039\mu\text{g/g}$ compared with the control fat skatole level, $0.057\mu\text{g/g}$. The statistical significance effect was not apparent with the fat indole levels where the scFOS treatment showed a non-statistically significant reduction of the fat indole concentration; control and scFOS treatments resulted in values of $0.024\mu\text{g/g}$ and $0.020\mu\text{g/g}$ respectively.

In carcass fat, boars exhibited increased levels of both skatole and indole ($P<0.001$). Back-transformed mean values for boars were $0.033\mu\text{g/g}$ indole and $0.077\mu\text{g/g}$ skatole, with the gilts displaying a mean indole concentration of $0.010\mu\text{g/g}$ and skatole $0.017\mu\text{g/g}$. The Swedish taint threshold for skatole of $0.2\mu\text{g/g}$ (Zamaratskaia et al., 2003), is lower than the UK taint threshold of $0.25\mu\text{g/g}$ (MLC Technical Division, 2005). Using the lower of these two values, of this study

population only 9.6% of the boars showed taint that would be recognized by consumers. Using the UK threshold level, only 7.7% of the boars would be recognized as tainted. No gilts were above this threshold, with maximum gilt level at 0.062µg/g.

Figure 2 shows the relationship between proximal and distal colon content pH level and the equivalent skatole concentration. Regression analysis of digesta skatole concentration on pH was significant ($P=0.009$), but with a low r^2 of 5.7%. A relationship between pH and digesta indole concentration was not found ($P=0.665$, $r^2=0.2\%$).

Figures 3 and 4 present the spread of the fat skatole and indole concentrations by slaughter LWT. There was no apparent pattern of fat skatole or indole concentration as related to the LWT, with only 1.9% of indole samples and 4.8% of skatole samples above the Swedish 0.2µg/g threshold of skatole related carcass taint. Regression of the individual fat skatole concentrations on LWT showed no positive relationship (r^2 0.4%, $P=0.468$). Similarly, when LWT was tested as a covariate during ANOVA of diet and gender effects, it showed no effect ($P=0.390$).

4 Discussion

Similar to this study, Mikkelsen et al. (2003) reported no improvement from an addition of scFOS on the growth rate of weaning pigs and this study found the addition of the 2g/kg scFOS showed no improvement in finisher pig growth

performance but also no negative effects on feed intake. Other studies have linked FOS with a reduction in feed intake (Gebbinck et al., 1999) but this difference may be linked to the types of FOS used and greater inclusion rates.

In terms of nutrition, both diets provided in excess of the recommended intake of lysine and tryptophan (Whittemore et al., 2003) suggesting the potential for skatole synthesis was present from unutilised amino acids and a high energy intake. The calculated lysine requirement for 120kg pigs growing at 0.93kg/day is 20.2g per pig per day. The diet specification, combined with the DFI, provided approximately 35.0g lysine. Whilst the tryptophan requirement would be 5.13g/day, this diet supplied 6.65g/day. As increased energy intake increases cell turnover, this may also have led to increased availability of degradable tryptophan from the gut cell wall apoptosis, (Raab et al., 1997).

In contrast to Knarreborg et al. (2002), this study showed no consistent effect of the scFOS in decreasing skatole concentration of faecal samples and at one sample point increased the faecal concentration of skatole.

The data from Knarreborg et al. (2002) and Xu et al. (2002) suggested that with increasing inclusion rates of scFOS, digesta skatole production decreased and production of skatole shifted away from skatole and towards increased indole production. In this current experiment, this relationship was inconsistent. The scFOS did show a tendency towards increased indole concentration in the proximal colon, but this was not evident in the distal colon.

Skatole production is sensitive to gut pH level (Jensen and Jensen, 1993). The increased digesta pH of the distal colon was associated with 57% greater concentration of skatole than in proximal colon digesta. Previously published research suggests that there is a narrow range of pH in which skatole is produced at quantity. In vitro work by Jensen et al. (1993), suggested that skatole production was greater at pH 6.5 compared to pH 5, but at pH 8 skatole production was reduced to a level lower than at pH 5 (Jensen and Jensen, 1993).

A factor which may affect skatole production and account for conflicting skatole production data is the nature of the substrate/pathway used to produce the skatole. Production directly from L-tryptophan or from indole-3 acetic acid requires different pH levels to produce maximum skatole. Optimal production of skatole from indole-3-acetic acid occurs between pH 6-7, whilst optimal skatole production direct from L-Tryptophan occurs at pH 5 (Jensen et al., 1995a).

The lack of relationship between skatole and indole in digesta could be linked with the lack of change in the digesta pH level from the scFOS which was also reported by Mikkelsen et al. (2003), where despite using 40g/kg FOS fed at weaning also found no corresponding decrease in gut pH. In contrast, Xu et al. (2002) contradicts these data and using a dose response in vitro study reported that increasing FOS supplementation (5g/kg, 10g/kg and 15g/kg) exerted an increasingly negative effect on pH. There are differences in the quantity of FOS used, the mode of action and therefore the effect of FOS but also differences between the in-vivo and in-vitro methodology used. As another variable in the live pig, Houdijk (1998) suggests that unless the pig is subject to challenge, FOS will have a limited effect on gut flora and

subsequent pH. The increased faecal skatole concentration shown in week 1 suggests the pigs were responding to stress, diet change and antibiotic treatment given at mixing and therefore allowing the gut microflora to respond to the scFOS and in this instance, scFOS acted to increase faecal skatole concentration. Kerley and Allee (2004) found, although in weaners, that 0.75g/d intake of scFOS increased faecal skatole concentration but an inclusion of 1.5g/d exerted a negative effect on faecal skatole. The weaner faecal concentration of skatole, found by Kerley and Allee (2004), was much lower compared with the current experiment using finisher pigs (0.12ug/g and 16.45ug/g respectively). There is a large difference between the physiological state of a weaner pig digestive tract compared with a finisher pig digestive tract with younger pigs being more susceptible to changes in fermentable raw materials (Houdjik et al., 1998) which may account for the differences in skatole production and the response to the scFOS. There are also large differences in feed/nutrient intake and therefore substrate for skatole production. The current experiment's primary increase in skatole concentration and lack of response thereafter suggests the experimental level of 2 g/kg scFOS inclusion would need to be increased for older pigs to manipulate faecal skatole production.

Despite the lack of effect on digesta and faecal pH, scFOS treatment showed a clear effect on fat skatole levels and effect also shown by Øverland et al. (2007), where the dietary inclusion of organic acids reduced plasma skatole but not skatole in digesta.

In this current study, the scFOS did not have a statistically significant effect on fat indole concentration, despite a numeric reduction, whereas Hansen et al. (2006)

and Hansen et al. (2008), found feeding an NSP reduced both fat skatole and indole. The conflicting responses apparent in these and other published research, a positive reduction apparent in Jensen et al. (1995b) and Jensen et al. (1997), and no effect Wiseman et al. (1999), Jensen (1997); and Kjos et al. (2010), may be due to differences in the type of NSP, its mode of action and inclusion levels of NSP. Many of these NSP sources have a much greater inclusion rate, from 29g/kg to 205g/kg and vary widely in their composition from pure FOS to fermentable fibre sources such as sugar beet pulp and non-fermentable fibre sources such as straw and consequently the fermentative conditions in the hindgut are very different.

The suggested mode of action with scFOS, inulin and SBP being the supply of easily fermentable carbohydrates subsequently increase microbial activity and decrease digesta pH, Lynch et al. (2007), Li et al. (2009), Jensen et al. (1995b), Knarreborg et al. (2002). Therefore, it is not just the inclusion rate but also the type of raw material and its hind gut fermentation properties which are important.

In previous research, gender did not effect faecal skatole concentration or gut pH difference (Jensen et al., 1995a; Mikkelsen et al., 2003). Therefore, combined with the lack of statistical difference on digests indoles, it was unexpected for the results to show an effect of gender on pH in the colonic digesta samples. As boars had increased fat skatole concentration compared with the gilts, the reduction of fat skatole by the scFOS was proportionately greater in the boars. This effect was similar to that found by Hansen et al. (2006), when feeding chicory as the form of NSP to both genders.

In agreement with the present results, Hawe et al. (1992) and Hansen et al. (1993) found no correlation between faecal and fat skatole concentrations. Although Jensen et al. (1995b) found a correlation between digesta skatole concentration and deposition in fat, the individual animals and their response to intestinal skatole varied widely. Whereas Knarreborg et al. (2002), found faecal skatole levels to be a good indicator of skatole production but the study used only entire males, which may account for the different conclusion. In the current study, the regression analysis of fat skatole against faecal skatole was calculated using boar only data (data not shown), and confirmed the Hawe et al. (1992) and Hansen et al. (1993) conclusion that faecal skatole was not a good predictor of fat skatole concentration ($p=0.723$, r^2 0.4%).

As reported previously, the boars exhibited increased fat skatole and indole concentrations up 65% relative to gilts, (Wiseman et al., 1999; Hansen et al., 2006). In this instance, this is unlikely to be due to greater aggression stress prior to slaughter (Hansen et al., 1993) as there was no difference in aggression levels measured by rindside damage. The prevalence of boar skatole concentrations above the 0.2 $\mu\text{g/g}$ taint threshold level was, at 9.6%, within the expected range of 4-11% suggested by Gill and Knowles (2003), but mean levels of boar fat skatole (0.078 $\mu\text{g/g}$) were similar to that found by Andersson et al. (1997b). The boar population mean of fat skatole concentration is much lower at than the previously reported national average of 0.13 $\mu\text{g/g}$ (Walstra et al., 1997). Knarreborg et al. (2002), suggest absorbed skatole is proportional to amount produced but despite the higher boar fat skatole concentration, intestinal skatole concentrations were not different between boars and gilts. This lack of gender difference in intestinal skatole combined with the gender effect on fat

skatole suggests the boars had a reduced hepatic clearance rate of skatole in comparison with the gilts (Jensen and Jensen, 1993). Boars have reduced skatole metabolism due to the androstenone degradation pathway in the liver affecting the skatole degradation pathway as indicated by (Friis, 1993). Rasmussen et al. (2011), showed that when male pigs were fed chicory, this increased the activity of the cytochrome P450 CYP1A2, 2A and 2E1, an important part of the skatole and androstenone degradation pathway in the liver. Rasmussen et al. (2011) could not define the mechanism of the effect on the CYP 450 enzymes but discussed the involvement of cytosolic receptors regulating their synthesis but also suggested that there were several other possibilities including indirect effect of altered hormonal or endogenous substrate concentrations through prebiotic effects on the intestinal flora.

Over the period from allocation until week 6, equivalent to the conventional finishing weight of ~90kg, both boars and gilts exhibited similar performance and efficiency. However, boars maintained performance and efficiency at the increased slaughter weights whereas gilts showed deterioration in performance and efficiency, as reported by Andersson et al. (1997), Weatherup et al. (1998) and Beattie et al. (1999). Despite the lack of difference in subcutaneous back fat levels between gender, when Weatherup et al. (1998) calculated the lean:fat ratio from dissection, it became apparent boars had an increased lean:fat ratio compared with the gilts, suggesting the gilts were depositing fat in other depots such as intramuscularly and in the body cavity (Latorre et al., 2003, Simm et al., 2004). This indicates that this back fat measure was not a reliable indicator of carcass fatness at these increased slaughter weights.

The back fat levels found in this experiment are much reduced compared to some previous heavy pig data which may be related to an age and breed effect. Bañón et al. (2004) reported entire males (Spanish Large White×Duroc females cross Landrace×Duroc males and Landrace×Large White females cross Large White males), with similar carcass weights of 95kg exhibiting back fat levels of 29mm. In UK pigs, Weatherup et al. (1998) found similar back fat P₂ values of 12.7mm and 14.7mm for carcass weights of 90kg and 100kg respectively.

5 Conclusions

To conclude, the dietary inclusion of 2 g/kg scFOS reduced carcass fat levels of skatole and reduced the risk of carcass taint but had little effect on colonic indolic compound concentration, digesta pH levels or pig performance. The reduction fat skatole in boars and to a lesser extent in the gilt may show the dietary inclusion of scFOS can positively improve the skatole levels in the carcass. Despite gender differences in efficiency and performance there was no interaction between gender and scFOS inclusion in these parameters. In general, boars were more efficient than gilts at this heavier weight range. At these increased slaughter weights, the subcutaneous back fat depth showed no difference between genders and results suggest backfat may be a poor indicator of total fat deposition at these liveweights. Increasing slaughter weight did not appear to greatly increase the prevalence of carcass taint from skatole above the reported national averages. Faecal and digesta levels of indolic compounds were not good predictors of indolic compound concentrations in carcass fat.

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688 Table 1: Diet Constituents (kg/t), proximate analyses by NIR and declared analysis

Raw Material	Control	Control plus scFOS	
Barley	100	100	
Wheat	346	344	
Wheatfeed	175	175	
Extracted Rapeseed	50	50	
Hipro Soya Meal	99	99	
Extracted Sunflower	45	45	
Limestone	11	11	
Lysine HCL	3.9	3.9	
Biscuit Meal	110	110	
Maize	49	49	
Salt	2.1	2.1	
Vitamins and Minerals	5	5	
Monocal Phosphate	4	4	
scFOS	--	2	
Diet Analysis (g/kg)	Control	Control + 2g/kg scFOS	Declared Analysis
Dry matter	888.1	883.6	890
Ether extract oil	42.3	43.7	34.5
Crude Protein	175.3	186.5	184.8
Ash	54.4	55.6	57.0
NDF			170.0
Digestible energy (MJ/kg)			13.00
Calcium			7
Phosphorus			3.6
Total Lysine			11.2
Total Methionine + Cysteine			5.5
Total Threonine			6.2
Digestible Lysine			9.0
Digestible Methionine + Cysteine			4.7
Digestible Threonine			5.3

689 * NDF not analysed by NIR analysis**Vitamin premix added to provide Vitamin A 8000IU/kg,
690 Vitamin D3 2000IU/kg, Vitamin E 50IU/kg, Vitamin K 2mg/kg, Vitamin B1 2mg/kg, Vitamin
691 B24mg/kg, Pantothenic acid 10mg/kg, Nicotinic acid 17mg/kg, Vitamin B6 2 mg/kg
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694 Table 2: Main effects and interactions of dietary inclusion of scFOS and gender on
695 performance parameters (n=16)

	Control		2g/kg scFOS			Significance		
	boars	gilts	boars	gilts	SEM	Gender	Diet	Interaction
<u>Live weight (kg):</u>								
Allocation	56.1	54.1	55.4	54.3	2.38	0.608	0.926	0.896
Week 6	91.6	89.0	94.8	89.5	0.96	0.009	0.153	0.283
Slaughter	122.7	125.2	125.1	124.1	0.792	0.459	0.537	0.114
<u>DLWG (kg):</u>								
Week 0-6	0.85	0.83	0.93	0.84	0.025	0.127	0.164	0.297
Week 6-slaughter	0.95	0.82	1.05	0.79	0.030	<0.001	0.425	0.136
Allocation-slaughter	0.90	0.82	0.97	0.82	0.020	<0.001	0.172	0.147
<u>DLTG (kg):</u>								
Week 0-6	0.43	0.43	0.48	0.43	0.015	0.051	0.105	0.169
Week 6-slaughter	0.46	0.39	0.49	0.39	0.016	<0.001	0.478	0.381
Allocation-slaughter	0.45	0.41	0.48	0.41	0.010	<0.001	0.135	0.113
<u>DFI (kg):</u>								
Week 0-6	2.47	2.47	2.50	2.38	0.051	0.373	0.598	0.373
Week 6-slaughter	3.13	3.17	3.40	3.00	0.102	0.162	0.878	0.096
Week 0-slaughter	2.76	2.81	2.85	2.68	0.059	0.395	0.764	0.165
<u>FCR:</u>								
Week 0-6	2.93	3.00	2.71	2.82	0.064	0.283	0.036	0.773
Week 6-slaughter	3.28	3.91	3.24	3.75	0.142	0.010	0.577	0.763
Allocation-slaughter	3.09	3.43	2.93	3.28	0.080	0.007	0.158	0.941

696 DLWG - daily liveweight gain; DLTG - daily lean tissue gain, DFI – daily feed intake, FCR – feed
697 conversion ratio

698 Table 3: Main effects and interactions of dietary inclusion of scFOS and gender on
699 carcass data (n=16)

	Control		2g/kg scFOS		SEM	Significance		
	boars	gilts	Boars	gilts		Gender	Diet	Interaction
Allocation to slaughter (days)	75	84	71	86	1.8	<0.001	0.638	0.156
Killing out %	73.9	75.2	72.9	75.1	0.38	0.006	0.294	0.347
Hot carcass wt (kg)	94.0	97.8	94.8	96.9	0.62	0.005	0.953	0.289
Cold carcass wt (kg)	90.8	94.2	91.2	93.3	0.65	0.008	0.780	0.412
Pre-slaughter back fat (mm P ₂) †	10.9	12.2	10.9	11.1	0.39	0.187	0.265	0.295
Carcass back fat (mm P ₂)	13.2	14.9	13.7	13.3	0.46	0.177	0.262	0.024
Carcass estimated lean (%)	60.1	59.0	59.7	60.0	0.35	0.418	0.541	0.158
Protein deposition rate (g/day)	99.2	94.4	105.6	93.6	2.53	0.001	0.274	0.158
Rindside damage (MLC 0-5 scale)	2.3	1.9	2.1	2.0	0.10	0.072	0.690	0.510

700 † measured ultrasonically on the live animal

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704 Table 4: Main effects and interactions of dietary inclusion of scFOS and gender on
705 indolic compound level ($\mu\text{g/g}$) in faeces, colon digesta and digesta pH (n=112)

	Control		2g/kg scFOS		SEM	Significance		
	boars	gilts	boars	gilts		Gender	Diet	Interaction
Wk 1 faecal skatole	13.30	16.40	19.22	19.38	1.984	0.416	0.030	0.464
Wk 1 faecal indole	4.50	4.77	4.44	6.14	0.754	0.201	0.391	0.349
Wk 6 faecal skatole	16.20	16.48	17.97	18.76	1.380	0.703	0.150	0.854
Wk 6 faecal indole	8.42	6.94	8.51	8.40	0.986	0.426	0.435	0.490
Slaughter faecal skatole	15.11	13.88	17.36	11.18	1.742	0.040	0.900	0.166
Slaughter faecal indole	10.27	8.73	8.06	9.20	1.038	0.849	0.412	0.209
Proximal colon skatole	6.12	5.39	4.06	4.57	1.143	0.929	0.214	0.591
Proximal colon indole	6.44	6.47	7.87	9.29	1.248	0.563	0.094	0.583
Distal colon skatole	8.77	7.71	9.96	8.78	1.269	0.383	0.380	0.962
Distal colon indole	6.28	5.29	5.48	6.52	0.680	0.972	0.756	0.142
Proximal colon pH	5.79	6.01	5.86	6.01	0.102	0.070	0.769	0.695
Distal colon pH	7.16	7.40	7.25	7.40	0.077	0.015	0.601	0.534

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Table 5: Main effects and interactions of dietary inclusion of scFOS and gender on indolic compound levels in carcass fat ($\mu\text{g/g}$), (n=112)

	Control		2g/kg scFOS		SEM	Significance		
	boars	gilts	boars	gilts		Gender	Diet	Interaction
Skatole	-1.031 (0.093)	-1.708 (0.020)	-1.201 (0.063)	-1.850 (0.014)	0.0584	<0.001	0.009	0.820
Indole	-1.435 (0.037)	-1.984 (0.010)	-1.541 (0.029)	-2.004 (0.010)	0.0547	<0.001	0.249	0.434

individual pig values; analysis was carried out on log transformed data and figures in brackets are back transformed means.

Figure 1: Mean ultrasonic back fat level (P₂ mm) versus live weight (kg) (week 2 to week 12 data)

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738 Figure 2: The relationship between digesta pH and skatole concentration in the
739 proximal (PC) and distal (DC) colon, ($r^2=5.7$, $p=0.009$).

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Figure 3: Fat indole concentration by live weight

Figure 4: Fat skatole concentration by slaughter liveweight