Effect of feeding fermentable fibre-rich feedstuffs lupine and chicory prior to slaughter with special emphasis on the effect on chemical boar taint in organic entire male and female pigs and technological meat quality

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Report in English with Danish Summary

Abstract

Boar taint is an off-flavour of pork caused primarily by skatole and, androstenone. Pig off-odour and flavour mostly caused by higher skatole concentrations in backfat. It is a problem in all types of pork production and is not restricted to entire male pigs. If uncastrated, 5-10% of Danish entire male pigs (100 kg liveweight) have > 0.25 ppm skatole in backfat and are then classified as boar tainted, having a markedly reduced value. Even backfat skatole values above 0.15 ppm enhance the off-odour for skatole sensitive consumers. An alternative way to reduce high skatole concentrations may be feeding with fibre-rich feedstuffs. This idea is based on previous studies which have demonstrated that 10% dried chicory or more in the feed reduces skatole in entire male pigs significantly after 7, 14 and 21 days of feeding, resulting in a significant reduction in perceived boar taint and thus an improvement in the flavour and taste of meat. Significantly decreased skatole concentrations and a tendency to increased eating quality have also been demonstrated by feeding 25% lupines to female and castrated male pigs during the whole fattening period. The question remains, however, whether the effects of lupines on skatole and other sensory characteristics of female and entire male pigs can be obtained when used only in the last 1 or 2 weeks before slaughter.

Two experimental replicates each consisting of 24 pigs (12 entire male and 12 female) was divided into three treatments according to litter and initial weight and kept in pairs (pens) of either female or entire male pigs. The male and female pigs were kept in different stables. The pairs of pigs have been fed three organic diets for either 1 or 2 weeks prior to slaughter of which two diets contained different fermentable fibre-rich feedstuffs (10% dried chicory root plus 90% organic control feed and 25% blue lupine seed plus 75% other organic feed components). These two treatments were compared with a control; where the pairs of pigs

were fed organic control concentrate ("conventional") either 1 or 2 weeks prior to slaughter (at approx. 104 kg liveweight). Levels of skatole and indole in blood plasma from *Vena jugularis* were monitored at the start of the experiment and just before slaughter, and skatole in backfat was measured at slaughter. Production results were registered (daily weight gain, FUp[1] per kg gain, slaughter weight, carcass meat percentage, warm and cold carcass weight), and after slaughter at Research Centre Foulum the following technological meat quality attributes were measured on *M. Longissimus dorsi* (LD): meat colour (L*, a*, and b* values), drip loss, pH measurements, temperatures and glycogen at 45 minutes and 24 hours post mortem.

There was a significant reduction in skatole in blood and backfat for both sexes by feeding 25% blue lupine one or two weeks prior to slaughter ($P<0.001$). The 10% (and 13.3%) dried chicory roots showed no significant effect. This is possibly due to error in the heat treatment of the roots during the drying process. A majority of the meat quality parameters were not significantly affected by either of the two dietary treatments. However, glycogen contents tended to be higher 45 minutes and 24 hours post mortem ($P<0.10$) and the drip loss lower in the lupine-fed pigs. There were clear tendencies to significant differences in production results as the 25% lupines showed negative impact on growth rate, feed conversion ratio, slaughter weight and carcass weight. Newly mixed entire male pigs showed worse performance than newly mixed female pigs during the short time experiment.

Keywords: Chicory, lupine, fibre, NSP, fructooligosaccharides, boar taint, skatole

[1]Feed Units – pigs; 1 FUp = 7.72 MJ

Sammendrag

Ornelugt er en afvigende lugt og smag som først og fremmest skyldes de to stoffer skatol og androstenon. Det er et problem som findes hos 5-10 % af danske DLY-hangrise ved en levendevægt omkring 100 kg. Imidlertid vides det, at sogrise og galte også kan have "ornelugt" eller rettere sagt griselugt/-smag eller fækal lugt/-smag (skatol). Skatol i rygspæk over 0,15 ppm alene opleves af sensitive forbrugere som kød med afvigende lugt og smag.
En måde til at få reduceret skatolkoncentrationen og forbedret spisekvaliteten kunne tænkes at være fodring med fiberrige langkædede kulhydrater. Baggrunden herfor er tidligere forsøg med rå og tørret cikorie rod og blå lupin frø. Et blandt flere forsøg med cikorie har tidligere vist, at 10 % eller mere af tørret cikorierod i foderblandingen reducerede skatolinholdet hos hangrise signifikant når der blev fodret hermed i 1, 2 eller 3 uger. I den sensoriske undersøgelse resulterede det i nedsat ornelugt og dermed en forbedring af spisekvaliteten. Tilsvarende vides, at 25 % blå lupiner reducerer skatolkoncentration i spæk hos galte og sogrise, men ikke om en sådan reduktion kunne ske allerede efter 1 eller 2 uger hos han- og sogrise, samt hvilken indflydelse dette ville have på spisekvaliteten.
Derfor gennemførtes to forsøgsgentagelser hver med 24 grise (12 han- og 12 sogrise) som blev fordelt på 3 forsøgsbehandlinger i henhold til kuld, begyndelsesvægt og køn således, at der var par af enten sogrise eller hangris i hver sti. Par af henholdsvis so- og hangrise blev opstaldet i forskellige stalde, så kønnene ikke skulle kunne påvirke hinanden. De parvis opstaldede grise blev fodret med 3 forskellige foderblandinger i 1 eller 2 uger før slagtning og slagtet ved en gns. levendevægt på 104 kg.. De to forsøgsfoderblandinger indeholdt fermenterbare fibre (henholdsvis 10 % tørret cikorie plus 90 % økologisk kontrol kraftfoder eller 25 % blå lupiner plus 75 % andre økologiske kraftfodermidler). De to forsøgsfoderblandinger blev sammenlignet med den økologiske standard kraftfoderblanding. Der blev målt skatol og indol i blodplasma fra *Vena jugularis* ved forsøgets påbegyndelse og lige før grisene blev bedøvet ved slagtning. 45 minutter efter slagtning blev udtaget nakkespækprøver til skatolbestemmelse. Produktionsresultaterne blev registreret (Daglig tilvækst, FEs per kg tilvækst, levende slagtevægt, varm og kold slagtevægt, kødprocent), og efter slagtning på Forskningscenter Foulum blev følgende teknologiske kødkvaliteter målt i *M. Longissimus dorsi* (LD): Varm og kold slagtevægt, kødprocent, kødfarve (L*, a*, and b* værdier), dryptab, pH målinger, temperaturer og glykogen 45 minutter and 24 timer post mortem.

Der blev fundet en stærkt signifikant reduktion i skatolniveauet både i blod og spæk for begge køns vedkommende efter både 1 og 2 ugers fodring med 25 % lupiner (P<0.001). 10 % (og 13,3 %) tørret cikorie reducerede derimod ikke skatolniveauet i blod og spæk signifikant i forhold til de kontrolfodrede sandsynligvis på grund af fejl i tørringsprocuduren. De fleste teknologiske kødkvalitetsegenskaber var ikke blevet påvirket af forsøgsbehandlingerne. Der var en tendens til at glykogenindholdet 45 minutter og 24 timer efter slagtning var højere hos de lupinfodrede og dryptabet mindre (P<0,10). Der var en klar tendens til at produktionresultaterne blev forringet ved fodring med 25 % lupiner (daglig tilvækst, FEs[2] per kg tilvækst, levende slagtevægt, varm og kold slagtevægt). Nyligt sammenblandede hangrise opnåede ringere produktionsresultater end nyligt sammenblandede sogrise i dette korttidsforsøg.

Nøgleord: Cikorie, lupiner, fibre, NSP, fructooligosaccharider, ornelugt, skatol

Introduction

Feed ingredients

Different feed components have been tested on their effect on skatole levels on digestive tract, faeces and backfat. Jensen et al (1995a) tested the effect of different diets, containing different sources of protein and fibre, on skatole production across the digestive tract and deposition in backfat. In spite of the variation between individual animals receiving the same diet, there was a clear effect of dietary components on skatole production and deposition. Raw potato starch (RPS) lowered skatole production in the colon, concentration in blood plasma and backfat in entire males, gilts and castrates (Losel and Claus, 2005; Losel et al., 2006; Zamaratskaia et al, 2005a, b; Zamaratskaia et al, 2006; Andersson et al, 2005; Chen et al., 2007). RPS reduced the production and absorption of skatole in the large intestine and the reduction was dose-dependent (Losel and Claus, 2005). Inclusion RPS did not influence the activity of cytochrome P450IIE1 and P450IIA6 and thus skatole metabolism (Zamaratskaia et al, 2005a). RPS has a low ileal digestibility and preferentially leads to microbial butyrate formation in the large intestine. Butyrate is the main energy source for the colonic epithelium

[2]Feed Units – pigs; 1 FUp = 7.72 MJ

(Smith et al, 1998). Mentschel and Claus (2003) showed that butyrate inhibits apoptosis of colon crypt cells thus less tryptophan from cell debris is available for microbial fermentation and skatole production (Claus et al., 2003).

Additions of non-digestible oligosaccharides, fructo-oligosaccharides/inulin (FOS), in the diet, have shown that decrease skatole levels in faeces, backfat and blood (Claus et al, 1994; Jensen and Jensen, 1998). In a study Hansen et al. (2006a) tested the influence of dry or crude chicory roots, which has high content of inulin (FOS), on skatole levels in blood plasma and backfat. Skatole in blood plasma was reduced to low levels after only 3 days of feeding 25% dried chicory roots and decreased further after 7 days and remained at a very low level until the end of the feeding period feeding for both crude and dried chicory. Skatole concentration in backfat was also very low in both crude and dried chicory fed pigs. The results for chicory-fed animals were similar also to those fed purified inulin, indicating that inulin (FOS) is the main component of chicory and responsible for this reduction (Hansen et al, 2006a). Further studies with 2.5, 5, 10 and 20 % dried chicory have demonstrated that 10% dried chicory or more in the feed reduced skatole in the blood and backfat of entire male pigs significantly after 7, 14 and 21 days of feeding, resulting in a significant reduction in perceived boar taint, related to skatole, and thus improved the flavour and taste of meat produced from entire male pigs (Byrne and Hansen, 2005; Hansen, 2005). The reduction in skatole level both in blood and backfat was dose-dependent so that the reduction was most pronounced with 20 percent chicory in the feed and the effect was seen after 1, 2 and 3 weeks feeding (Hansen, 2005). Also, the 25% lupine-based diet during the whole fattening period reduces skatole levels in castrated male and female pigs (Hansen and Claudi-Magnussen, 2004). However, the short time effect on entire male and female pigs chemical and sensory boar taint was unknown.

1.1 Chicory roots, Fructans and Inulin

Chicory inulin extracted from the root is a mixture of oligo- and polymers of GpyFn (terminal glucose), FpyFn with different degree of polymerization (DP). The DP varies from 2 to 60, with an average of 12. Chicory is also contains glucose, sucrose and fructose (De Leenheer, 1996) and 1% of native chicory inulin contains branches (De Leenheer and Hoebregs, 1994).

Inulin and oligofructose are characterised as non-digestible carbohydrates (Roberfroid and Slavin, 2000; Cumming et al., 1997), due to the beta configuration of the anomeric C_2 in their fructose monomers, that form β 2→1 glycosidic linkages. They resist digestion in the small intestine by the human digestive enzymes (Alles et al., 1996) and they served as substrate for

the microflora in the large intestine. The end products of the microbial fermentation are lactic acid and SCFA (Buddington et al., 1996). They are readily fermented by beneficial types of bacteria and less effectively by the potential harmful colonic bacteria. They promote the growth of the beneficial bifidobacteria, lactobacilli and eubacteria instead of *Staphylococci, Salmonela, Listeria, Shingella, Escherichia coli, Veillonella* and certain clostridia, which are considered pathogenic (Gibson and Roberfroid, 1995). They are characterised as prebiotic (Gibson and Roberfroid, 1995; Buddington et al., 1996; Roberfroid et al., 1998). Many authors have reviewed the physiological and nutritional effects of inulin and oligofructose in humans and animals (Roberfroid and Delzenne, 1998; Boeckner et al, 2001; Roberfroid, 2005; Flickinger et al, 2003; Verdonk et al., 2005). The positive effect on gut microflora (promote the growth of beneficial in expense of harmful bacteria), modulate lipid metabolism and insulinemia, increase mineral absorption (Ca and Zn), reduce the risk of colon carcinogenesis and other intestinal infections and in some cases their effectiveness in the control of pathogens is equal to those of antibiotics.

1.2 Lupine

Lupine (*Lupinus spp.*) is valuable source of protein and energy for livestock. Based on its chemical composition, it is characterised by negligible levels of starch and high levels of soluble and insoluble NSP and oligosaccharides. The content and chemical composition of lupines NSP varies between species and cultivars (van Barneveld, 1999). The total level of NSP is high (405 g/kg) compared with other protein sources such as soybean meal, peas and faba beans (217, 180 and 190 g of NSP per kg respectively) (Bach Knudsen, 1997). The soluble fraction of the NSP is higher in the kernel compared to hulls (197 vs. 76 g of NSP per kg), and the alkaloids are found only in the kernel (0.13 vs. <0.01 g/kg) (Fernandez and Batterham, 1995). The main component of the crude fibre is hemicellulose whereas in other legume seeds, peas and faba beans have cellulose (Bach Knudsen, 1997). Lupines contain high levels of rafinose oligosaccharides, which are indigestible in the stomach and small intestine. These compounds fermented in the large intestine producing CO_2, H_2, and CH_4 (van Barneveld, 1999). Lupine-seed meal has high ileal digestibility of lysine (0.82) (Fernandez and Batterham, 1995; Batterham et al., 1984).

1.3 Fermentation in the large intestine

Carbohydrates that reach the colon are fermented by the microflora to obtain energy for their growth and maintenance. The end products are SCFA, acetate, propionate and n-butyrate, and their proportion depends on the type of substrate that enters in the colon, the microflora composition and the lumen pH. The end product of microbial fermentation of endogenous and/or dietary protein in the large intestine is branched-chain volatile fatty acids (isobutyrate, valerate and isovalarete) (Macfarlane and Allison, 1986; Macfarlane et al., 1992) and potentially toxic metabolites such as ammonia, amines, phenols and indoles (skatole and indole), (Smith and Macfarlane, 1996; Macfarlane et al., 1992). These compounds are responsible for the malodour in pig slurry which can be reduced by decreasing the crude protein and providing the essential amino acids in the diet (Hobbs et al, 1996) or providing another source for energy for microbial fermentation, such as chicory roots (Jensen and Hansen, 2006) or RPS (Willig et al, 2005).

The availability of substrate in terms of carbohydrates, for energy, and nitrogen stimulate microbial growth. Intestinal bacteria can utilise ammonia as a source for nitrogen for their own growth when sufficient fermentable carbohydrates are available. By inclusion fermentable carbohydrates such as inulin the production of potential toxic compounds in the colon are reduced (Jensen and Hansen, 2006). There is a shift of N excretion as bacterial protein in the faeces instead of urea in urine after the addition of fermentable carbohydrates in the diet (Canh et al, 1997; Nahm, 2003). This leads to a marked reduction in ammonia from pig houses by feeding inulin (Hansen et al., 2006a).

1.4 Aim of the study

The aim of this study was to test the effect of feeding 10% dried chicory roots or 25% blue lupine seeds for 7 or 14 days prior to slaughter on skatole levels in blood and backfat as well as on eating quality of *M. Long. dorsi* in entire male and female pigs. Moreover, animal performance was registered and technological meat quality parameters were measured on the *M. Longissimus dorsi* (LD) muscle. The sensory boar taint results are not included in this report due to delayed money from FØJO III for sensory eating quality analysis of *M. Long. dorsi.*

Material and Methods

2.1 Experimental design

The experiment was conducted in two replicates at the organic farm Rugballegaard. Each replicate lasted over a period of fourteen days. For each replicate, twenty-four finishing pigs were used (twelve males and twelve females). At live weight of 90 kg, the pigs were assigned to one of the three feeding treatments according to their live weight, litter and sex (Table 1) and moved to the fattening pens. The live weight at slaughter day should be around 100-105 kg. The pigs were housed in pairs of the same sex in the pens and the two sexes were kept in separate pig houses. The pigs were weighted on day 0, before they received the experimental diet. They were weighted again on day 7 and the heaviest from each pen was chosen to be slaughter the next day (day 8). The remaining pig from each pen was slaughtered on day 15. Blood samples were collected from *Vena jugularis* in the morning before the pigs were moved to the fattening pens (day 0) and just before stunning at the abattoir (either day 8 or 15). Blood samples were analysed for skatole and indole concentration in the plasma. Back fat samples were collected on each slaughter day for skatole equivalents determination and meat quality parameters on the carcass were measured on the *M. Longissimus dorsi* (LD) muscle.

Table 1. Experimental design for the finishing feeding period of the three treatments with organic concentrate, dried chicory and blue lupine from avg. 90 kg live weight until slaughter at avg. 104 kg after a feeding period of 1 or 2 weeks.

Replicate[1)]	Treatment	No of pigs	Experimental Units	Feed Composition
1	Control	8	4 pens of 2 pigs[2]	100% Organic Concentrate
	Chicory	8	4 pens of 2 pigs[2]	90% Organic Concentrate + 10% Dried Chicory
	Lupine	8	4 pens of 2 pigs[2]	75% Organic Concentrate + 25% Blue Lupine
2	Control	8	4 pens of 2 pigs[2]	100% Organic Concentrate
	Chicory	8	4 pens of 2 pigs[2]	86.7% Organic Concentrate + 13.3% Dried Chicory
	Lupine	8	4 pens of 2 pigs[2]	75% Organic Concentrate + 25% Blue Lupine
Total		48	24 pens of 2 pigs	

[1)] Experimental replicate 1 was executed first half of October 2006 and 2nd replicate first half of November 2006.
[2)] 2 pens with males + 2 pens with females in sex separated stables. The heavier of the 2 pigs in a pen was slaughtered after a 1 week feeding period and the last after a 2 weeks feeding period.

2.2 Animals and housing

All forty-eight experimental animals were Danish crossbred pigs of Duroc sires and crossbred dam Danish Landrace x Large White (D(LY)), produced at the Organic Research Station at Rugballegård (Horsens). From weaning until the beginning of each of the two experimental replicates of the experiment, the pigs were kept in single-sex pens. Each pen had an indoor area of 13 m^2, partly slated floor and deep bedding covered with straw. They had access to outdoor, partly covered area, with solid floor of 13 m^2.

On day 0 in each of the two experimental replicates, the pigs were assigned to one of the three treatments and moved to the fattening pens. Females were kept in separate stables from entire males, in order to avoid visual and olfactory contact and to avoid earlier sexual maturity in both sexes and maybe elevated levels of androstenone in males, which contribute to boar taint. The pigs were housed in pairs of the same sex. The pens had slatted and solid floor. Each pen has 12 m^2 indoor and outdoor areas (24 m^2 in total). The pens were cleaned daily to avoid increased skatole and indole concentration in the subcutaneous fat (Hansen et al, 1994).

During the experimental period of fourteen days, the pigs were fed slightly restricted (3 kg/pig/day) and had free access to clean drinking water. They received the first meal, the afternoon after moving to the fattening pens (day 0). The meal was provided twice a day, in the morning (8:00 am) and in the afternoon (15:00 pm). Any feed refusal from the previous day was recorded before receiving the morning meal. The last meal before slaughter was given the afternoon before slaughter in the morning next day.

2.3 Dietary treatments

Before the initiation of the experiment the pigs were fed an organic certified concentrate diet according to Danish recommendation for growing pigs (Madsen et al., 1990) and ad libitum clover grass silage. Organic pigs in Denmark must have access to some kind of roughage according to organic farming.

Treatment 1 was the control group (CON) and was receiving3 kg feed/pig/day of 100% organic concentrate diet, which is around 95% according to the Danish scale for finishing pigs (Madsen et al, 1990). The animals in treatment 2 (DC) were fed 3 kg feed/pig/day with 10% dried chicory plus 90% organic concentrate, at the first experimental replicate and 13.3% dried chicory plus 86.7% organic concentrate, at the second replicate. Treatment 3 was the lupine group (LUP) fed 3 kg feed/pig/day given 25% lupine plus 75% organic concentrate diet. The chicory fed pigs was not supplied with further protein in the concentrate diet as the amount of protein needed for growth and lean meat were fulfilled (15-16%) according to current Danish recommendations for nutrients to finishing pigs (Danish Bacon and Meat Council, 2002).

During the experiment, clover grass silage was offered to the pigs ad libitum. The feed intake of the roughage was not registered, because it had shown from previous studies that the proportion on the daily energy, from the roughage, was less than 5% of the total daily energy due to the high concentrate intake (Danielsen et al., 2000; Hansen et al., 2006b).

The inulin-rich variety of chicory (*Cichorium intybus* L. var Orchies) was grown organically and harvested the last days of October 2005. It was stored outside 1 to 1.5 month, in large heaps covered with straw. A fast mincer (Wienchen, Copenhagen, Denmark) chopped the crude chicory roots after storage. The chopped roots were dried in a drying cupboard at a temperature just bellow 65 ^{O}C for 48 hours. Dried chicory was stored in dry place until it was

ground and mixed with the other ingredients at the private feed mill. The three diets were conditioned shortly at 80 ^{O}C according to the Danish regulation for destroying any possible Salmonella contamination before agglomeration. The control and experimental diets were provided to the pigs pelleted.

The amount of dried chicory roots was increased from 10% to 13.3% in the DC diet in the second replicate because the resulted level of skatole in backfat from the pigs in the first replicate was not decreased compared to the control (CON) fed It was found by several analysis of the dried chicory used for this experiment that the dried chicory contained less (35-36%) fructans (inulin), compared to 46% in earlier experiments. The analysis for low molecular sugars in the DC diet also supports this. It was decided to increase the amount of dried chicory in the second replicate and the pigs were fed with 13.3 % dried chicory (coarse ground dried chicory) and 86.7 % organic concentrate (pelleted). The dried chicory was mixed with the pelleted concentrated feed just before the delivery of the meal.

A commercial variety of Blue lupines (*Lupinus angustifolius* var. Prima) were used. The lupine-seed meal was ground and mixed with the other ingredients.

The composition and the nutrient content of the control and the two experimental diets are presented in Table 2.

Table 2. Composition and nutrient content of the control (CON) and the experimental diets (DC and LUP).

	CON	DC	LUP
Composition (g/kg)			
Dried Chicory	-	10.0	-
Blue Lupine	-	-	25.0
Soybean cake	8.0	7.2	2.0
Rape seed cake	10.0	9.0	7.0
Rape seed	1.3	1.1	1.6
Peas	15.0	13.5	5.0
Sunflower cake	7.0	6.3	5.2
Wheat	21.3	19.2	22.1
Barley	10.0	9.0	10.0
Oat	25.0	22.5	20.0
Lime stone	1.1	1.0	1.1
Mono calcium phosphate	0.7	0.6	0.4
Salt	0.5	0.4	0.5
Vitamins and minerals	0.2	0.2	0.2
Total	100.0	100.0	100.0
Calculated Analysis (g/kg DM)			
FUp	1.0	0.99	0.98
Dry Matter	901.8	892.10	894.4
Crude Protein (N x 6.25)	202.2	183.9	217.4
Crude Fat	59.4	54.1	60.2
Crude Fibre	83.7	76.2	103.6
Ash	61.9	61.1	58.5
Lysine	10.1	9.2	9.8
Methionine	3.3	3.0	2.7
Tryptophan	2.4	2.2	2.3

*FUp = Scandinavian Feed Units for pigs; 1 FUp=7.38 MJ NE

2.4 Slaughter procedure

On the day of slaughter, the pigs were transported from the Organic Research Station at Rugballegård to the experimental abattoir at Research Centre Foulum (100 km), by a special

truck for animal transportation. All pigs arrived to the abattoir of Research Centre Foulum at 8.00 a.m. after 1.5 hour of transport from Rugballegaard. The pigs were slaughter in two groups according to their sex (first the males and after the females) and in randomise order according to their treatment (diet) within the groups. The pigs were stunned by 85% CO_2 for three minutes, exsanguinated, scalded at 62 ^{O}C for 3 minutes. Thereafter, they were cleaned and eviscerated. The whole procedure lasted 30 minutes. Unchilled carcasses were split in two equal halves and placed in a room at 12 ^{O}C. One hour after exsanguination, the carcasses were placed in the chill room at 4 ^{O}C, with intermittent airflow. Normally 4 ^{O}C is reached approximately in 12 hours post mortem in carcasses similar in size, meat percentage and weight, in this chill room.

2.5 Sampling and meat quality parameters

Blood samples were taken from the *Vena vulgaris* in heparinised vacuum tubes on days 0 and again just before stunning (either on day 8 or 15). Blood samples were kept on ice until the transport at the laboratory. The samples were centrifuged in 2000xg for 20 min in 4 ^{O}C for plasma separation and plasma was stored in -80 ^{o}C until skatole and indole analysis.

Forty-five minutes post mortem, back-fat samples from the neck region, approximately of 100 g, were taken for determination of skatole equivalents at the Danish Crown, Ringsted, Denmark.

Duplicate pH (pH_{45min}) and temperature (T_{45min}) measurements were made 45 min post-mortem in muscle *M. Longissimus dorsi* (LD) at the last rib in the cranial direction. Temperature was measured with a Testo 110 thermometer (Testo, Germany) and pH measured with a mobile pH-meter (826 pH-mobile, Metrohl, Switzerland) equipped with a probe type glass electrode (Metrohm LL Glas Electrode WOC, Switzerland) calibrated in pH 4,01 and 7,00 IUPAC buffers (Radiometer, Denmark) at 35 ^{O}C (carcass temperature).

2.6 Meat quality indicators and attributes 24 h post mortem

Temperature (T_{24h}) and pH (pH_{24h}) were measured as described for measurements taken 45 min post mortem, except for calibration of the pH electrode, which was done at 4 ^{O}C (carcass temperature).

Water-holding capacity (WHC) was measured in LD muscle, 10 cm from the last rib in the cranial direction as the drip loss using the plastic bag method described by Honikel (1998). An approximately 100 g muscle sample, without visual fat, was placed in a netting bag and then suspended in an inflated bag, ensuring that the sample does not touch the bag. After storage period of 48 hour at 4 ^{O}C, the sample was taken from the bag, blotted dried and weight again. Drip loss was expressed as percentage of the initial weight.

Meat colour was measured on cut of LD samples using a Minolta Chroma Meter CR-300 (Osaka, Japan). Samples allowed to bloom for 1 hour at 4 ^{O}C prior the measurement. The Chroma Meter was calibrate on a white tile (L*= 96.94, a*= 0.10, b*=1.83). The tristimulus parameters L*, a*, b* represent lightness, redness and yellowness respectively. The measurements were done in five different, fixed sites of each chop surface. The average of the five measurements was used for each animal. Carcass lean meat percentage was predicted 24 h post mortem by Fat-O-Meter (SFK-Technologies, Denmark), based on backfat thickness of the last lumbar vertebra, 8 cm from the midline, and backfat and LD muscle thickness between the last third and fourth rib, 6 cm from the midline.

2.7 Chemical analysis

2.7.1 Feed analysis

The content of low molecular sugars in the experimental diets was determined as described by Larsson and Bengtsson (1983).

The chemical analysis for the low molecular sugars content of the four diets and the pure dried chicory showed the remarkable difference of the fructans (inulin) content between the experimental diets (Table 3). The dried chicory diets (10 and 13.3 %) contain four times more fructans (inulin) than the other two diets (CON and LUP). The amount of fructans that the individual pig consumed was 26.4, 112.5, 168 and 26.7 g/day for CON, 10% DC, 13.3% DC and LUP respectively, if we assumed that the first week each pig from the pair ate an equal amount of feed (3 kg/pig/day).

Table 3: Content of low molecular sugars (% of DM) of the four diets (CON, 10% DC, 13.3% DC and LUP) and Dried chicory.

	CON	10% DC	13.3% DC	LUP	Dried Chicory
Low molecular sugars (total)	3.46	8.49	10.27	3.22	54.68
Glucose	0.29	0.40	0.36	0.21	0.81
Fructose	0.15	0.66	0.87	0.16	5.55
Sucrose	2.14	3.68	3.46	1.96	11.93
Fructans (Inulin)	0.88	3.75	5.60	0.89	36.39

2.7.2 Glycogen determination

The LM samples were taken at the last rib in the cranial direction, were frozen in liquid nitrogen immediately after sampling, and stored at −80 ^{O}C until analysis. Glycogen content was determined in 25 mg muscle sample, which was boiled with 5 ml of 1 M HCl at 100 ^{O}C for 2 hours. The supernatant was analysed for glucose residues (Passonneau and Lowry, 1993) and expressed in micromoles of glucose residues per gram of wet muscle.

2.7.3 Skatole and indole in plasma and skatole equivalents in backfat.

High-Performance Liquid Chromatography (HPLC) method described by Hansen-Møller (1998) measured skatole and indole in blood plasma.

Skatole equivalents in backfat were measured by the automatic spectrophotometric method described by Mortensen and Sorensen (1984) at the Danish Crown, Ringsted, Denmark.

2.8 Statistical Analysis

Due to the fact that the pigs were housed in pairs and the feed consumption was registered for the pair, each pair was considered as one experimental unit. The production and meat quality results for each experimental unit were calculated as the average of the results of the individual pigs of the pair.

All the data were analysed with the Statistical Analysis System version 9.1 (SAS Institute, Cary, NC, USA). The GLM procedure was used to calculate the least-squares means and the standard error of the means for the performance and meat quality attributes results. The GLM model included the fixed effect of treatment (diet), sex, pen replicate, replicate (experimental) and the interactions between treatment and sex and treatment and replicate (experimental). Preliminary statistical analysis of logarithmically transformed data for skatole and indole concentration in plasma and skatole equivalents in backfat was done, which gave the same results with untransformed data and thus untransformed data were used. For the production results, the initial live weight was used as covariate for live weight at slaughter, warm and cold carcass weight, daily gain, FCR and FUP per kg gain. In the variable of lean meat percentage the warm carcass weight were used as covariate. For skatole and indole in plasma at slaughter, skatole and indole at day 0 were used as covariate. As there were found no effect of pen replicate and no interactions between treatment and replicate (experimental) for any of the variables of the experiment the fixed effect pen replicate and the interaction was taken out in the final models.

In order to see the effect of feeding 7 or 14 days before slaughter on boar taint variables (skatole and indole in plasma), it was assumed that the pigs in the same pen ate equal amount of feed during the first week and the results for the individual pig were used. The heaviest pig from each pen (pair) was slaughter on day 8 and the remaining on day 15. The GLM model included the fixed effect of treatment (diet), sex, animal replicate, replicate (experimental), feeding time (7 or 14 days) and the interaction between sex and treatment and between slaughter day and treatment. The results are presented as least square means and standard error. Significant difference were tested for P-value<0.05.

Results

3.1 Animal performance

All the pigs remain healthy during the whole experimental period. Each pair consumed all the daily meal without any refusal. The performance results between the control and chicory fed pigs did not differ significantly but the lupine group showed lower performance (Table 4). The chicory diet contains less crude protein than the other two diets. The amount of crude protein for each diet was 20.22, 18.39 and 21.74 % (Dry matter basis) for CON, DC and LUP

respectively (Table 1). The chicory-fed pigs did not supplement with further protein as the requirements for lean meat for finishing pigs were fulfilled (15-16%) (Danish Bacon and Meat Council, 2002). The live weight at slaughter was lower for the lupine group and tended to be significant (P=0.06) compared with the control and chicory group. The warm and cold carcass weight was also tended to be significantly different (P=0.055) between the control and chicory compared to lupine group. One pig from the chicory and one from the lupine group were excluded from the statistical analysis, for FCR and FUp per kg gain calculation, because they were outliers. The daily gain of the control and chicory fed pigs were similar but the lupine group tended to grow less (951, 912 and 720 g/day, P=0.107), and consequently the lupine fed pigs showed higher FCR (4.4 vs. 3.29 and 3.36 kg/kg for the control and chicory group respectively, P<0.05).

Despite the higher initial weight of the males (but not statistically different) compared to the female pigs, they showed worse performance results than the females in all the measured performance variables, except the lean meat percentage of the carcass which was not significantly different (Table 4).

Table 4: Production results (least-square means and standard error) for the three treatments (CON, DC and LUP) and two sexes (male and female pigs).

	CON	DC	LUP	s.e.	Significance of Treatment	Males	Females	s.e.	Significance of sex
Weight (kg)									
Day 0	93.2	93.6	95.8	2.5	NS	95.6	92.8	2.0	NS
Slaughter	104.9^{b}	104.4^{ab}	102.4^{a}	0.7	(*)	103.1	104.7	0.5	(*)
Warm Carcass	77.7	77.3	75.9	0.5	(*)	76.4	77.6	0.4	(*)
Cold Carcass	75.4	74.9	73.6	0.5	(*)	74.0	75.27	0.4	**
Lean Meat (%)	61.4	61.6	61.75	0.26	NS	61.5	61.7	0.2	NS
Daily gain (kg)	0.951	0.912	0.721	0.073	(*)	0.77	0.95	0.057	(*)
FCR (kg/kg)	3.31^{d}	3.37^{d}	4.37^{f}	0.25	**	4.27	3.10	0.212	**
FUp per kg gain	3.29^{g}	3.32^{g}	4.31^{h}	0.25	**	4.22	3.07	0.21	**

[a,b,c,d,f,g,h,] Least-squares means that do not share a common superscript letter, within the row, differ significantly (P<0.05).

¶FUp = Scandinavian Feed Units pigs; 1 FUp=7.38 MJ NE.

(*), * and *** indicate statistically significance differences of P<0.1, P<0.05 and P<0.001 respectively. NS = no significant difference

There was no interaction between treatment and sex and treatment and replicate.

3.2 Meat quality parameters 45 minute and 24 hours post mortem

Two pigs, one from the control and one from the chicory group, were excluded as outliers from the statistical analysis for temperature 45 minutes post mortem. The meat quality attributes on LD muscle, pH, temperature (45 minutes and 24 hours post mortem), drip loss, colour values (L*, a* and b* representing the lightness, redness and yellowness respectively), Glycogen and pH did not differ significantly between the three treatments (Table 5). The ultimate pH (24 hours post mortem) was 5.63 for the control and chicory group and 5.61 for the lupine group. The glycogen content, 45 minutes and 24 hours post mortem, measured as glucose residues was higher for the lupine compared to chicory fed pigs ($Glycogen_{45min}$: 46.71 vs. 38.84 and $Glycogen_{24hour}$: 29.65 vs. 23.66 µmol/g wet muscle ($P<0.05$). The chicory fed pigs had the lowest glycogen content but did not differ significantly from the control group ($Glycogen_{45min}$: 38.84 vs. 41.51and $Glycogen_{24hour}$: 23.66 vs. 25.39 µmol/g wet muscle). No differences were found between the control and the lupine group for glycogen content 45 minutes and 24 hours post mortem

Entire male pigs had lower pH value, 45 minutes post mortem which approach to be significantly different (6.45 vs. 6.52, $P<0.1$) but significantly higher ultimate pH (5.67 vs. 5.57, $P<0.001$) (Table 5). Carcass temperature, measured on LD muscle, 24 hours post mortem was higher in male pigs (3.46 vs. 3.31, $P<0.001$). Glycogen content found to be higher in female pigs 45 minutes after slaughter compared to male pigs (45.5 vs. 39.21 µmol/g wet muscle, $P<0.05$) but 24 hours post mortem did not differ significantly between the two genders. Male pigs had darker meat (measured as L*, 55.73 vs. 57.96, $P<0.05$).

Table 5: Meat quality attributes (least-square means and standard error) 45 minutes and 24 hours post mortem for the three treatments (CON, DC and LUP) and two sexes (male and female pigs).

	CON	DC	LUP	s.e.	Significance of treatment	Males	Females	s.e.	Significance of Sex
45 minutes									
pH	6.49	6.44	6.52	0.03	NS	6.45	6.52	0.026	(*)
Temperature (^{O}C)	36.9	36.9	37.6	0.3	NS	37.35	37.0	0.2	NS
Glycogen (µmol/g wet muscle)	41.51^{ab}	38.84^{a}	46.71^{b}	1.83	**	39.21	45.50	1.50	**
24 hours									
pH	5.63	5.63	5.61	0.017	NS	5.67	5.57	0.014	***
Temperature (^{O}C)	3.42	3.36	3.38	0.027	NS	3.46	3.31	0.022	***
Glycogen (µmol/g wet muscle)	25.39^{cd}	23.66^{c}	29.65^{d}	1.38	**	24.96	27.51	1.13	NS
Colour									
L*	55.97	57.48	57.09	0.577	NS	55.73	57.96	0.47	**
a*	7.37	7.6	7.65	0.224	NS	7.75	7.33	0.18	NS
b*	5.6	6.2	6.07	0.216	NS	5.80	6.12	0.18	NS
Drip loss (%)	3.83	3.73	3.35	0.33	NS	3.46	3.81	0.27	NS

^{a,b,c,d} Least-squares means that do not share a common superscript letter, within the row, differ significantly ($P<0.05$).
$^{(*)}$, * and *** indicate statistically significance differences of $P<0.1$, $P<0.05$ and $P<0.001$ respectively. NS = no significant difference
There was no interaction between treatment and sex and treatment and replicate

3.3 Skatole levels in plasma and backfat

Skatole and indole concentrations in plasma at the initiation of the experiment were equal for the pigs of the three feeding groups (Table 6). There was no interaction between sex and treatment for skatole concentration in plasma and backfat at the end of feeding period. Feeding dried chicory roots did not lower skatole levels in plasma significantly. On the other hand, the lupine fed pigs had very low skatole concentration in plasma at slaughter (2.429 vs. 1.948 vs. 0.425 μg/l for CON, DC and LUP respectively, $P<0.001$). None of the lupine fed pigs had skatole levels in plasma higher than 1.063 μg/l in contrast with the control and chicory treatments where some individual pigs had high skatole levels in plasma. Indole concentration in plasma at slaughter did not differ between the control and the tested diets but there was difference between lupine and chicory group (0.969 vs. 0.500, $P<0.05$).

There was a tendency to significant difference in skatole concentration in plasma between the two sexes, at the beginning of the experiment, with entire males being higher than females (2.182 vs. 1.696 μg/l, $P<0.1$). In the end of the feeding period skatole levels in blood plasma differed significantly between male and female pigs (2.034 vs. 1.167, $P<0.05$). Indole concentration in blood plasma did not differ between sexes at the beginning and end of the experiment.

Table 6: Skatole and indole concentration in blood plasma (µg/l) (least-square means and standard error) for the three treatments (CON, DC and LUP) and two sexes (male and female pigs).

	CON	DC	LUP	s.e.	Significance of Treatment	Males	Females	s.e.	Significance of sex
Skatole (µg/l)									
Day 0	1.868	1.945	2.005	0.2241	NS	2.182	1.696	0.1830	(*)
At slaughter	2.429^{b}	1.948^{b}	0.425^{a}	0.3082	***	2.034	1.167	0.2471	**
Indole (µg/l)									
Day 0	0.511	0.702	0.667	0.1300	NS	0.640	0.613	0.1062	NS
At slaughter	0.641^{dc}	0.500^{c}	0.969^{d}	0.135	**	0.782	0.624	0.095	NS

^{a,b,c,d} Least-squares means that do not share a common superscript letter, within the row, differ significantly (P<0.05).
*, ** and *** indicate statistically significance differences of P<0.1, 0.05 and 0.001 respectively. NS = no significant difference.
There was no interaction between treatment and sex and treatment and replicate

The control group had the highest skatole level in backfat (Figure 1) followed by the chicory and lupine group. There was not significant difference between the control and chicory group. Skatole concentration in backfat for the lupine fed pigs differs significantly from the control (0.033 vs. 0.130, P< 0.01) and the chicory group (0.033 vs. 0.111, P< 0.01). The two sexes differed in skatole levels in backfat as males had higher levels than females (0.117 vs. 0.065 µg/g fat, P<0.05). There was an excellent correlation between skatole in backfat and blood plasma (r= 0.94; P<0.0001, Figure 2).

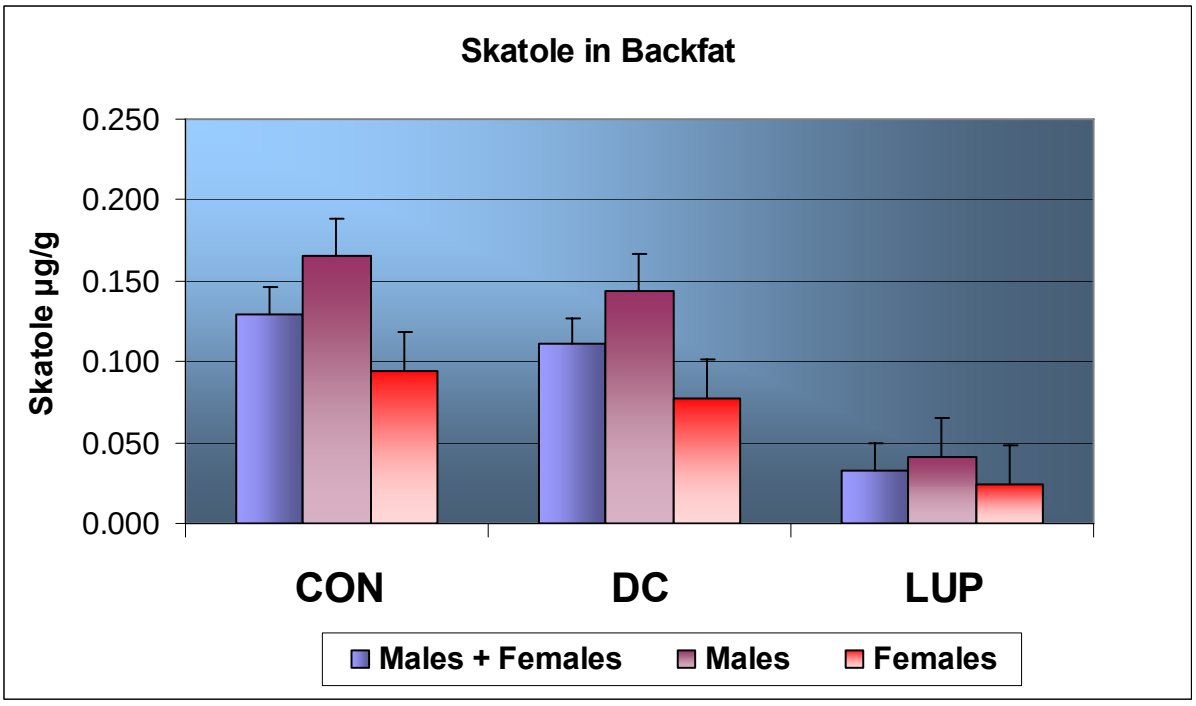

Figure 1: Skatole equivalents in backfat (µg/g fat) (least-square means ± standard error) for males, females and males + females for the three treatments (CON, DC and LUP) (Significance of treatment, P<0.05, significance of sex, P<0.05).

With the assumption that the two pigs in the pen ate the same amount of feed (3 kg/pig/day) we can treat the data for individual pigs instead of experimental units. Only one pig from the lupine fed group had skatole levels in backfat higher than 0.10 µg/g fat (Table 7, Figure 2), which had 0.115 µg/g fat and was the one of all pigs that had the highest skatole concentration in blood plasma at the initiation of the experiment. None of the female pigs had skatole level in backfat higher than 0.151 µg/g fat. One out of eight entire male pigs from the control group and two out of eight from the chicory group had skatole concentration in backfat above 0.2 µg/g fat. The pigs from the chicory fed group, which exhibited the limit had 0.235 and 0.315

µg/g fat and the one from the control group had skatole levels in backfat equal to 0.27 µg/g fat.

Table 7: Number of pigs (males and females) in different skatole concentration intervals in backfat for the three treatments

		< 0.10	0.101 - 0.150	0.151 - 0.199	>0.199
CON	**Males**	1	2	4	1
	Females	6	2	0	0
DC	**Males**	3	1	2	2
	Females	5	3	0	0
LUP	**Males**	7	1	0	0
	Females	8	0	0	0

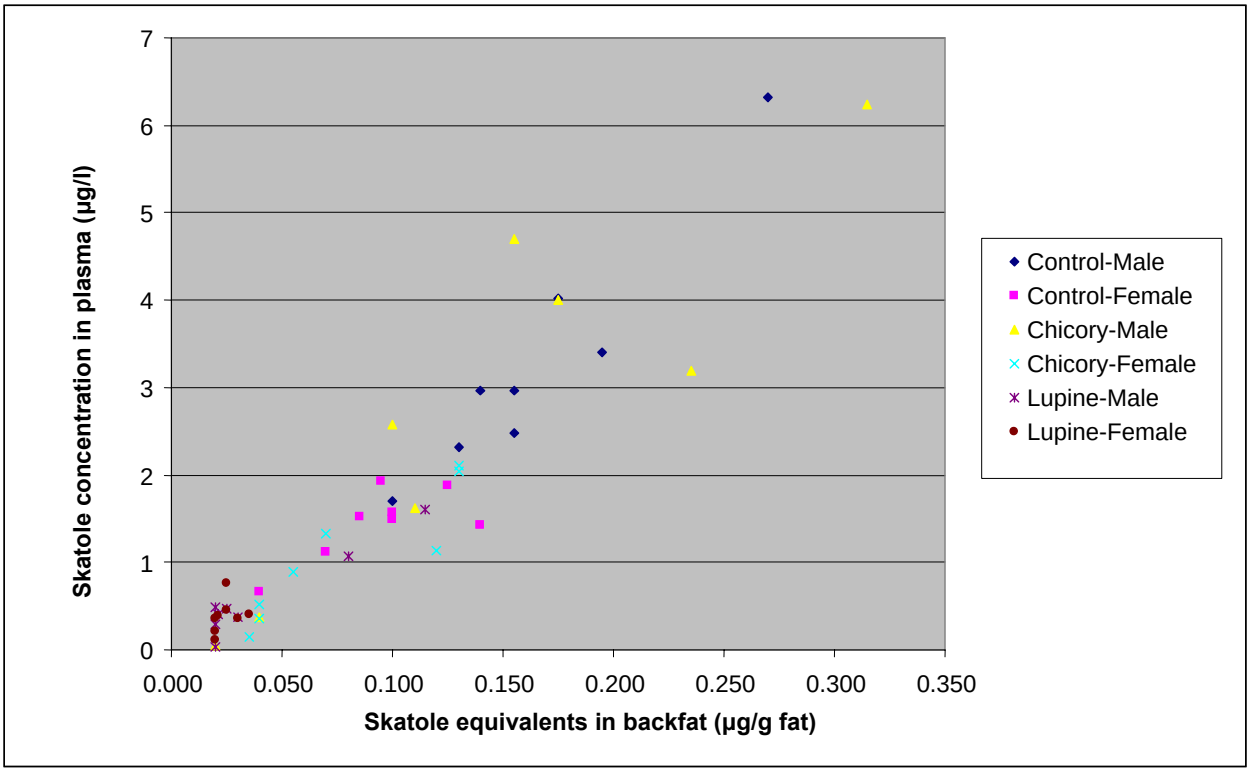

Figure 2: Scatter plot of the raw data for skatole equivalents in backfat and skatole concentration in plasma for the two sexes (entire male and female pigs) receiving the three diets (Control, Chicory and Lupine).

There was no interaction between treatment and feeding periods (7 or 14 days) before slaughter, as there was a remarkable reduction of skatole in plasma and backfat in the lupine fed pigs after one week feeding and followed by a further numeric but not significant reduction after the second week (Table 8). The control and chicory fed pigs did not differ significantly, irrespectively the time of feeding of the experimental diets. On the other hand, the lupine group had lower skatole levels in plasma and backfat compared to the chicory and control group in the first week ($P<0.05$) and differ significantly only from the control group the second week of feeding ($P<0.05$).

Table 8: Skatole concentration in plasma (µg/l) and backfat (µg/g fat) (least-square means and standard error) for the three treatments (CON, DC and LUP) in the two different feeding periods (7 and 14 days after receiving the control and experimental diets).

	Skatole in plasma (µg/l)			**Skatole in backfat (µg/g fat)**		
	7 days	**14 days**	**s.e.**	**7 days**	**14 days**	**s.e**
CON	2.242^{b}	2.557^{d}	0.377	0.122^{f}	0.138^{h}	0.020
DC	2.251^{b}	1.649^{dc}	0.377	0.121^{f}	0.100^{gh}	0.0198
LUP	0.625^{a}	0.280^{c}	0.377	0.037^{e}	0.029^{g}	0.020
s.e.	0.377	0.377		0.020	0.020	

^{a,b,c,d,f,g,h} Least-squares means that do not share a common superscript letter, within the column, differ significantly ($P<0.05$).
There was no interaction between treatment*sex, treatment*feeding period, and . treatment*feeding period*sex.

4. Discussion

The aim of this study was to investigate the effect of feeding fibre rich feedstuffs (dried chicory or blue lupines), 7 or 14 days prior to slaughter, on meat quality characteristics in entire male and female pigs, with special emphasis to chemical boar taint and sensory meat quality with special emphasis on sensory boar taint. In this study, only skatole levels in blood plasma and backfat and no androstenone levels were measured because it was shown from a previous experiment that feeding dried or crude chicory did not affect androstenone levels except in one of the three trials included in the experiment (Hansen et al, 2006a).

The results from this study failed to demonstrate that feeding 10% or 13.3% dried chicory roots a short time (1 and 2 weeks) prior to slaughter can reduce skatole levels in plasma and backfat significantly. Claus et al. (1994) and Jensen and Jensen (1998) have shown that inclusion of purified inulin or fructo-oligosacharides (FOS) reduce skatole level in blood plasma and backfat. In a recent study, Hansen et al. (2006a) clearly demonstrated that

substituting 25% of the daily energy intake with dried or crude chicory root reduced skatole levels in blood plasma and backfat significantly. They found a significant skatole reduction after one week of feeding dried chicory, which remained with crude chicory roots in low levels until the end of the ninth week of the experimental period. Skatole concentration in backfat at slaughter was also in very low levels. The same reduction on skatole in plasma and backfat were obtained, substituting 14% of the daily energy intake with purified inulin (corresponds to the amount of inulin in 25% dried chicory). Consequently, inulin is the most important component responsible for skatole reduction. In further studies, (Hansen, 2005) feeding 10 or 20% of dried chicory for one, two or three weeks before slaughter clearly demonstrated that skatole levels in both blood plasma and backfat decreased from the first week and remained at low levels until the end of the experiment. Feeding 5% dried chicory for 7, 14 or 21 days prior to slaughter reduce skatole levels in blood plasma and backfat but the effect does not seem to be effective enough for pigs with high skatole levels at the initiation of feeding. In the present study feeding 10 or 13.3% dried chicory failed to reduce skatole levels in blood plasma and backfat. However, the amount of inulin (fructans) in the chicory diet was found to be lower (around 36%) compared with the dried chicory from previous experiments (around 46%) and other sections of the same chicory crop after drying, which indicate a fault drying procedure and a drying temperature above the 65 ^{o}C recommended. However, the lower fructan level by it self (inulin) can not explain the noticed failure to reduce skatole levels in blood and backfat alone in the 2nd replicate with 13.3% dried chicory. So maybe something important has happened to the dried chicory root fibres not measurable by our chemical analysis for fructans, which has more or less spoiled the expected change from a protein to a carbohydrate fermentation pattern (Jensen & Hansen, 2006).

The amount of yellow peas in dried chicory and control diet was 13.5 and 15% whereas in the lupine diet was 5%. Yellow peas have shown increased skatole levels in backfat but only in one study (Lundstrom et al, 1994) and the level of skatole in the control and chicory treatments were not unnormal high compared to earlier studies. However, starch and protein from peas is sometimes less digestible comparing to that from wheat, barley and maize (Wiseman, 2006; Graham and Aman, 1987) resulting in higher amounts of undigested starch and protein that reaches the colon. Undigested starch and protein is a good source for microbial protein fermentation and might increase microbial activity and thus skatole production. You could in such cases expect that undigested tryptophane in the colon ferment

to more skatole than normal and by that increase the skatole concentration in blood and backfat of pigs from all sexes (Losel et al., 2006; Lundstrom et al, 1994) and smaller amounts of dried chicory would not have the necessary effect on skatole reduction (Jensen, B.B. personal communication).

Chicory inulin is a mixture of fructo-oligosaccharides and fructose polymers and the degree of polymerization varied between 2 and 60, with average of 12 (Gibson et al, 1994). The fructans and inulin content of chicory have been found to be decreased after the second week of storage at 2 ^{O}C and the reduction continued until the 10th week, whereas sucrose, glucose, fructose were increased (Ernst et al, 1995). Chicory roots used in this study were stored outdoor for one to one and a half month before drying in December 2005, which might influence not only fructans and inulin content but also the DP and not least if they have received freezing temperatures. Some oligosaccharides (DP<20) have been found to be fermented in the terminal ileum (FOS) or the proximal large intestine (transgalactosylated oligosaccharides), and these are not available for microbial fermentation in the distal colon (Mikkelsen et al, 2004; Houdijk, 1998).

Inclusion of 25% of blue lupines reduced skatole levels in blood plasma to very low levels from the first week of feeding and remained at low levels until the end of the second week of feeding. Skatole concentration in backfat at slaughter was also very low. The results from this study are similar with those of Hansen and Claudi-Magnussen (2004) who found that 25% of lupine reduced skatole concentration in backfat in castrated male and female pigs when fed lupines during the whole growth period. Jensen and Jensen (1998) found similar results with entire males. Blue lupines have high content of soluble NSP (Fernandez and Batterham, 1995), which can be used as energy source for the microbes in the large intestine. Inclusion of fermentable carbohydrates in the diet has shown a change from protein to carbohydrate fermentation decreased potential toxic compounds such as skatole and p-cresol (Jensen and Hansen, 2006) and there was a shift of N excretion to microbial protein (Canh et al, 1997; Nahm, 2003).

A strong correlation between skatole concentration in blood plasma and backfat has been found in several studies (r=0.90 to 0.98, P<0.001) (Tuomola et al., 1996; Hansen et al., 1997; Hansen-Møller, 1998) as in this study.

The control and chicory diet contain different amounts of crude protein and there was not differences in production results. The chicory fed pigs did not supplement with further protein as the protein requirement for finishing pigs were fulfilled (Danish Bacon and Meat Council, 2002). The same findings have been observed when 25% of the daily energy intake was substituted with dried or crude chicory (Hansen et al., 2006a).

The lupine diet contains the highest amount of crude protein but resulted in lower performance compared to the control and chicory groups. The presence of 25% lupine of the variety Prima used in this study have had a negative effect on the utilization of other dietary nutrients and subsequent negative effect on pig performance in an earlier study by Fernandez and Danielsen (2006) and they found that inclusion of 12.5% of lupines in the diet did not affect pig performance negatively and suggest that inclusion of maximum 15% would not affect pig performance negatively. Different cultivars of lupine specie contain high or low amounts of anti-nutritional factors (alkaloids, total tannins, oligosaccharides and trypsin inhibitor), which affected the feed intake of pigs and consequently their performance (van Barneveld, 1999). *Lupinus angustifolius* that was used in this study contains very low amounts of alcanoids and thus did not affect to feed intake.

In this short time (1 and 2 weeks) study in the finishing period just before slaughter, the entire male pigs showed lower production results (live weight at slaughter, warm and cold carcass weight, daily gain, FCR and FUp per kg gain) compared to the female pigs, but they had similar lean meat percentage. However, entire males compared to gilts have been found to have higher growth rate and better feed efficiency over the whole fattening period (Squires et al, 1993). Entire males are considered more aggressive and active than gilts (Newberry and Wood-Gush, 1988) and in this study, large entire male pigs were mixed in pairs (just as the female pigs) and housed in the same pen for one week before slaughter showing more aggressiveness and fighting for dominance than the gilts. This possible more fighting among the male pigs compared to the female pigs might have impaired the feed conversion ratio and growth rate. This point to the fact that entire males should not be mixed as finishing pigs and/or mixed before transport and/or at the abattoir due skin damage and DFD problems (high ultimate pH) (Warriss & Brown, 1985; Warriss et al., 1998).

5. Conclusion

Skatole concentration in blood plasma and backfat in entire male and female pigs can be reduced to low levels with inclusion of 25% of blue lupines in the diet for 7 or 14 days prior to slaughter but this amount decreased animal performance. Inclusion of 10 or 13.3% of dried chicory in the diet did not reduce skatole levels in both blood plasma and backfat in this study. However, the amount of inulin (fructans) in the chicory diet was found to be lower (around 36%) compared with the dried chicory from previous experiments and other dried sections of the same chicory root crop, which point in the direction of a worse drying procedure and maybe the drying temperature has been above the 65 ^{o}C recommended for drying. Newly mixed entire male pigs showed worse performance than newly mixed female pigs during the short time experiment. Meat quality attributes were not much affected with inclusion of fibre rich feedstuffs.

6. Future studies

- Influence of drying procedure and temperature on fructan quantity and quality (inulin) of dried chicory roots needs further investigation.
- Combined use of dried chicory roots and blue lupines (no more then 12-15%) may affect the total fermentation pattern in the intestine in a positive way and by that decrease infections more effectively and give better production and meat quality results? (Awati, 2005; Awati et al., 2006).

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