Org. Agr. (2019) 9:127–138
https://doi.org/10.1007/s13165-018-0216-z

Chicory and red clover silage in diets to finishing pigs—influence on performance, time budgets and social interactions

Magdalena Presto Åkerfeldt · J. Nihlstrand · M. Neil · N. Lundeheim · H. K. Andersson · A. Wallenbeck

Received: 13 February 2018 / Accepted: 2 May 2018 / Published online: 17 May 2018
© The Author(s) 2018

Abstract Ley crops can be preserved as silage and can serve as a locally produced feedstuff/enrichment for pigs. It is important to determine the potential for using ley crops grown on-farm in pig production and to evaluate dietary inclusion of different roughage types on pig performance and behaviour. This study examined the influence of access to chicory or red clover silage, in combination with a restricted feeding regime, on pig performance, time budgets and social behaviour. In total, 72 finishing pigs were evenly allocated to three treatments: chicory silage, red clover silage and a control. Pigs in the control treatment were fed 100% commercial liquid feed according to the standards for growing/finishing pigs, while pigs in the chicory and red clover treatments were fed 80% commercial diet (energy basis) and whole-crop chicory or red clover silage ad libitum. Pigs in the chicory silage and red clover silage treatments grew 15 and 10% slower, respectively, than pigs in the control treatment; however, the slower growth rate was not as pronounced as the reduction of energy allowance in the commercial feed. Further, the pigs fed red clover silage had lower feed conversion ratio (based on the commercial cereal-based feed) than pigs fed chicory silage or the control diet, indicating that the red clover silage contributed some energy and nutrients to the finishing pigs. Moreover, pigs fed chicory or red clover silage were more active than control pigs and performed more feed-directed behaviours and less behaviours directed towards other pigs and pen fitting.

Keywords Activity behaviour · Finishing pigs · Forage · Growth · Organic · Social interactions · Time budget

M. Presto Åkerfeldt (✉) · M. Neil · H. K. Andersson
Department of Animal Nutrition and Management, Faculty of Veterinary Medicine and Animal Sciences, Swedish University of Agricultural Sciences, SLU, Box 7024, 750 07 Uppsala, Sweden
e-mail: magdalena.akerfeldt@slu.se

J. Nihlstrand · N. Lundeheim · A. Wallenbeck
Department of Breeding and Genetics, Faculty of Veterinary Medicine and Animal Sciences, Swedish University of Agricultural Sciences, Uppsala, Sweden

A. Wallenbeck
Department of Animal Environment and Health, Faculty of Veterinary Medicine and Animal Sciences, Swedish University of Agricultural Sciences, Uppsala, Sweden

Introduction

In commercial pig production, access to rooting material such as straw improves pig welfare, as it increases the opportunities for pigs to perform important species-specific behaviours like foraging and exploration (SJVFS 2017). Roughage provision, in addition to straw, can further increase the time pigs spend eating and foraging (Olsen et al. 2000) and therefore meets the need of pigs to explore and forage to a greater extent (Høøk Presto et al. 2009). Pigs in conventional pig production systems have limited access to rooting material and are often kept in barren environments, which may redirect their motivation for foraging and exploration behaviour towards pen fittings and other pigs in the pen, sometimes leading to injurious behaviours (EFSA 2007). Provision of straw has been found to reduce such behaviour, while additional access to roughage increases foraging behaviour and reduces the incidence of aggressive behaviour even further (Høøk Presto et al. 2009; Presto et al. 2013).

In production systems where growing/finishing pigs are provided with roughage, e.g. organic production systems, this roughage is intended to supply nutrients and behavioural enrichment for the pigs (EC 2008). According to Wallenbeck et al. (2014), roughage can contribute some nutrients to growing/finishing pigs. If suitable roughage types are already grown on-farm, they can be preserved as silage and fed to pigs as a locally produced feedstuff, contributing to more self-sufficient and sustainable production (Wallenbeck et al. 2014). Forage often consists of grass and legume species and sometimes also herbaceous flowering plants. The most commonly grown legume species in Europe is clover, particularly red clover (*Trifolium pratense*) and white clover (*Trifolium repens*). Clover is commonly included in crop rotations due to its ability to fix nitrogen from the atmosphere and is often sown together with different grass species. Chicory (*Cichorium intybus*) can also be included in mixed leys. It is a perennial herb with a deep root system, which makes it persistent to drought, and it is high yielding and can be grown in temperate climates. This makes it a beneficial complement to other forage crops and gives a stable and persistent ley (Foster 1988). Chicory has a relatively high content of lysine in the leaves, but a lower amount of crude protein content than legumes (Crawley 2015). Inclusion of chicory in pig diets has been shown to favour Lactobacillus in the intestinal microflora, which may have a prebiotic effect (Ivarsson 2012).

Pigs in modern pig production, including the majority of organic pigs produced in Europe, are breed crosses, with a Landrace*Yorkshire crossbred sow and a Hampshire, Duroc or Piétrain sire. The dam breeds are selected for good reproduction in combination with high growth and the sire breeds are selected for high lean meat growth and effective feed conversion. Pigs have the capacity to digest and use nutrients from roughage to some extent, but inclusion of roughage in the diet of growing/finishing pigs can reduce the ileal digestibility of nutrients (Andersson and Lindberg 1997a, 1997b; Carlsson et al. 1999; Edwards 2003; Wallenbeck et al. 2014). In efforts to achieve sustainable organic pig production, it is important to evaluate the effect and validate the potential for using additional roughage, such as silage, as a nutrient source to modern crossbreed pigs.

The aim of the present study was to investigate the effect of access to chicory and red clover silage, in combination with a restricted feeding regime, on performance, time budgets and social behaviours in two pig crossbreeds used in commercial organic pig production in northern Europe.

Materials and methods

The experiment was performed at the Swedish Livestock Research Centre, Funbo Lövsta, Uppsala, Sweden, during July–August 2014. The study was approved by the Uppsala Ethics Committee on Animal Research (ethics approval number C86/14), which is in compliance with EC Directive 86/609/EEC on animal experiments.

Animals, housing, diets and treatments

A total of 72 finishing pigs, 36 Yorkshire × Hampshire crosses (YxH) and 36 Yorkshire × Duroc crosses (YxD), from nine litters in one production batch, were included in the study. At weaning (5 weeks of age), the litters were split and the piglets were distributed to 18 pens, with four pigs per pen. At an age of approximately 67 days (mean 67 days ± standard deviation (SD) 1.2 days) and a live weight of approximately 30 kg (33.6 ± 4.1 kg), the pigs were moved from the farrowing unit to a growing/finishing unit. Each pen consisted of two females and two males (one sex of each cross type YxH and YxD) and these groups were kept together throughout the experimental period. The male pigs were immunocastrated with Improvac™, with their first injection at 77 days of age and their second at 105 days. The experimental period started when the pigs were at an approximate live weight of 80 kg (81.5 ± 8.0 kg) and an average age of 115 days (115 ± 1.2 days). The study continued until slaughter, which occurred at approximately 110 kg live weight (108.6 ± 10.0 kg) and an average age of 147 days (147 ± 1.2 days). The pens consisted of a concrete floor in the lying and feeding area and a slatted dunging area (one-third of pen area). Total pen area was 5.76 m^2, giving a floor area of 1.44 m^2 per pig. The lying area was 1.8 m × 2.2 m and the slatted area was 1.8 m × 1.0 m. The partitions between pens in the lying area were solid walls, with a rack for silage placed 0.75 m above the floor. The partitions between pens in the slatted area were gates with metal bars. There was a wet feed trough (1.8 m long) in the front of each pen, in the lying area. One water nipple was placed in the slatted area. All pigs had access to straw (approximately 0.5 kg per pen and day), all pigs were individually monitored for disease and injuries by the staff every day and all pens were cleaned daily.

The study included three treatments: chicory silage, red clover silage and a control, with six pens of four pigs (total 24 pigs) per treatment. All pigs were fed a wet commercial cereal-based diet three times a day (generally at 8–10, 15–16 and 17–22 h) in the feed troughs. Dry feed was mixed with water prior to feeding and the wet feed was distributed to each pen by an automatic computerised feeding system (Skiold Datamix AB).

The pigs in the control treatment were fed 100% commercial feed according to the standard feeding and nutrient recommendations for growing/finishing pigs (Andersson et al. 1997). During the experimental period, they were provided a maximum feed ration of 25.6 MJ NE/day. The pigs in the chicory and red clover treatments were given 80% commercial diet (energy basis), i.e. 20.5 MJ NE/day, and an ad libitum supply of whole-crop (stem, leaf and flower) chicory or red clover silage in the silage rack. The silage racks were filled with new silage three times per day. The silages were from the first cut, harvested in June 2014. Samples of the silages were pooled into bulk samples for analysis. The nutritional composition of the commercial diet and silages is presented in Table 1.

Of the 72 pigs, one pig in the red clover treatment was tail-bitten 2 days prior to the start of the experimental period. This pig was removed from the pen and placed in a disease treatment pen, where it was kept until slaughter. It was excluded from the study.

Performance

Feed intake of the commercial diet for all pigs in the pen was recorded on a daily basis by the computerised feeding system and feed conversion ratio was calculated pen-wise. All pigs were weighed on the first day of the experimental period. When the pigs in each pen reached an average live weight of 108.6 kg (± 10.0 kg), their final weight was recorded and they were all sent to slaughter the following day. At slaughter, the carcass weight was recorded before cooling and lean meat content was determined with the Hennessy Grading Probe (Hennessy Grading Systems, Auckland, New Zealand; Sather et al. 1991). Daily growth from start of the experiment to slaughter was calculated as follows: (live weight on day before slaughter − weight at experiment start) / (slaughter date − start date).

Behaviour observations

All pens had a camera device installed over the slatted floor, which recorded the pigs day and night throughout the experiment. Behaviour observations were made based on the recorded video material, by the same person in every case. The pigs were observed for two consecutive days on two occasions (week 2 and week 4) during the experimental period, in order to estimate their time budgets and social interactions. To measure the time budgets of the pigs, instantaneous scan sampling was performed every hour during daytime (between

Table 1 Chemical composition and energy value of commercial feed and the silages

	Commercial feed	Chicory silage	Red clover silage
Dry matter (DM, %)	87	26.3	29.6
Net energy (NE), MJ^{-1} kg DM	10.7[a]	7.7[b]	7.9[b]
Gross energy (GE), MJ^{-1} kg DM	–	18.2	18.7
Crude protein (CP), g^{-1} kg DM	161	162	158
Crude fat, g^{-1} kg DM	48	–	–
Ash, g^{-1} kg DM	58	114	88
Crude fibre, g^{-1} kg DM	63	231	244
NDF, g^{-1} kg DM	–	379	385

[a] Estimated from metabolisable energy (ME) content in commercial feed (MJ^{-1} kg)/DM and NE = 0.75 × ME

[b] Estimated according to Lindberg and Andersson (1998), where energy digestibility (dE%) = 94.8 + (− 0.93 × NDF %). Digestible energy (DE) = dE × GE, ME = 0.95 × DE and NE = 0.75 × ME

7.00 and 19.00 h). At each scanning, the activity (eating feed, eating silage, drinking, nosing/rooting pen floor, nosing/biting pen fittings, nosing/biting other pig and doing nothing), body posture (lying, sitting and standing) and location of the pigs in the pen (in lying area and in slatted area) were recorded as described in Table 2.

Social interactions were observed and recorded continuously for 5 min three times per day (at 11.15, 13.45 and 17.30 h) on the same days as the scan sampling. The social interactions were divided into pig performing an interaction and pig receiving an interaction. The definitions of the social interactions by performing pigs (nosing, nibbling/biting, tail biting, head knocking, climbing, lifting, pushing, belly massaging, biting on pen fittings and eating/rooting silage) are presented in Table 2. The receiving pig's reaction to a social interaction was recorded as no reaction, avoid and return approach. Different social interactions were recorded as new events, regardless of whether they were performed by the same pigs or several different pigs. A new event was recorded as soon as new pigs interacted or when the interaction stopped for 3 s or more, and then started again.

Chemical analyses

Feed samples were freeze-dried, milled through a 1-mm sieve and then analysed for dry matter (DM) content by drying at 103 °C for 16 h. Ash content was analysed by combustion at 550 °C for 3 h. Nitrogen (N) was

Table 2 Ethogram of pig behaviours recorded from the video material

Category	Variable	Definition
Body posture (scan sampling)	Lying	Lying on the side of sternum, straight or bent legs
	Sitting	Front feet on the ground, back legs in lying position
	Standing	Standing on all four feet or walking
Location in pen (scan sampling)	In lying area	In the lying area
	In slatted area	At least one leg in the slatted area
Activity (scan sampling)	Eating feed	Snout in feed trough
	Eating silage	Snout touching silage rack
	Drinking	Snout touching water nipple
	Nosing/rooting pen floor	Nose touching pen floor (also slatted floor)
	Nosing/biting pen fittings	Snout touching pen fitting
	Nosing/biting other pig	Snout touching other pig
	Doing nothing	Snout in the air
Social interactions–performing pig (continuous sampling)	Nosing	Snout touching other pig
	Nibbling/biting	Nibbling or biting another pig
	Tail biting	Holding another pig's tail in the mouth
	Head knocking	Approaching another pig with rapid head movement and open mouth
	Climbing	At least one hoof/leg on top of another pig
	Lifting	Snout under the body of another pig and lifting upwards
	Pushing	Pushing another pig with any part of the body in order to displace it, no biting
	Belly massaging	Pig massaging another pig's belly or throat
	Biting pen fitting	Biting pen fitting
	Eating/rooting silage	Eating silage and rooting close to silage rack
Social interactions–receiving pig (continuous sampling)	No reaction	No change in body position or activity of the receiving pig
	Avoiding	Head turned away or pig moving away from the performing pig
	Returning approach	Receiving pig approaching the performing pig with head/snout

determined by the Kjeldahl method (Nordic Committee on Food Analysis 1976) using a 2020 Digestor and a 2400 Kjeltec Analyser Unit (FOSS Analytical A/S Hilleröd, Denmark). Correction of the crude protein (CP) content for losses of N at freeze-drying was performed according to NorFor (Nordic feed evaluation system). Neutral detergent fibre (NDF) was determined with ND solution (100%), amylase and sulphite (Chai and Udén 1998). Crude fat (EG fat) was determined according to the method described in the Official Journal of the European Communities (EU 1984), using a 1047 Hydrolysing Unit and a Soxtec System HT 1043 Extraction Unit (FOSS Analytical A/S). Crude fibre content was analysed with the SLL method according to conventional Swedish analytical methods for feed and plant material (Jennische and Larsson 1990). Gross energy (GE) content was measured with an Isoperibol bomb calorimeter (Parr 6300, Parr Instrument Company, Moline, IL, USA).

Statistical analyses

Statistical analyses were performed with the Statistical Analysis System, version 9.4 (SAS 2017). The effect of treatment on performance was evaluated with Proc MIXED. The statistical model included treatment (chicory silage, red clover silage or control), genotype (YxD or YxH) and gender (female or vaccinated entire male pigs) as fixed effects. Pen and litter were included as random effects in the model. Two-way interactions were tested and included in the model if found to be significant ($P < 0.05$). Pig was the experimental unit for carcass and all performance variables except feed consumption and feed conversion ratio, where pen was regarded as experimental unit. The model for the (pen-wise) feed consumption and feed conversion ratio included only treatment (chicory silage, red clover silage or control) as a fixed factor. Initial weight was included in the model as a covariate for the analysis of daily weight gain, while carcass weight was included in the model as a covariate for the analysis of lean meat content.

Descriptive statistics on behaviour variables were calculated using Proc FREQ and MEANS. The effect of treatment on time budgets and social interactions was evaluated using Proc MIXED. Differences between treatments in pigs' time budget in terms of body posture, pen location and activity (percent of time) and social interactions with other pigs (average number of interactions in the pen per observation occasion) were analysed with pen average as the experimental unit. The statistical model included the fixed effects of treatment (chicory silage, red clover silage or control) and observation occasion (week 2 or week 4), and the random effect of pen. For the variable eating roughage, only the chicory silage and red clover silage treatments were included in the fixed effect of treatment. Residuals of the variables were examined for normal distribution using Proc UNIVARIATE, where the Shapiro-Wilks test for normality and normal probability was considered, and all were found to be normally distributed. Results are expressed as least square mean, unless otherwise stated.

Results

Performance

There was a significant effect of treatment on growth rate of the pigs (Table 3). Pigs fed chicory had 15% lower daily growth rate and pigs fed red clover 10% lower daily growth rate than pigs in the control treatment. The allowance of the commercial feed was 20% lower (energy basis) in the silage treatments and consumption of the commercial feed was correspondingly 20% lower for pigs in pens with silage treatments than for pigs in pens with the control treatment (2.0 kg feed/day for pigs in both the chicory and red clover treatments compared with 2.5 kg feed/day for pigs in the control treatment). Feed conversion ratio based on intake of the commercial feed was lower among pigs in the red clover treatment than among pigs in the chicory and control treatments (Table 3). Silage consumption and silage residues were not recorded, so estimation of feed conversion ratio based on total feed and silage intake was not possible. Pigs in the chicory treatment had the numerically lowest carcass weight, followed by pigs in the red clover treatment and pigs in the control treatment (77.6, 81.5 and 83.3 kg, respectively), with the difference between the chicory treatment and the control being statistically significant ($P = 0.036$). A similar pattern was found for dressing percentage (73.5, 74.3 and 76.0%, respectively; significant difference between chicory treatment and control ($P = 0.018$)). Lean meat content did not differ between treatments (Table 3).

No difference in performance was found between genotypes (YxH or YxD) or between genders (female

Table 3 Performance and carcass quality of pigs fed 100% commercial feed (control) or 80% (energy basis) commercial feed with ad libitum access to either chicory or red clover silage. Data are presented as least square means, pooled standard error (SE) and F-value. $N = 71$ pigs (chicory silage = 24 pigs, red clover silage = 23 pigs, control = 24 pigs). Treatment means within rows with different superscripts are significantly different ($P < 0.05$)

	Treatment					
	Chicory silage	Red clover silage	Control	SE	F-value	*P* value
No. of pigs	24	24	24			
Initial weight, kg	80.4	82.9	80.5	1.99	0.9	0.431
Final weight, kg	105.6	109.7	110.2	2,49	1.5	0.231
Daily weight gain, g	787^{a}	833^{a}	930^{b}	28.1	8.1	0.001
Commercial feed conversion ratio, kg feed^{-1} weight gain	2.4^{a}	2.2^{b}	2.5^{a}	0.06	7.4	0.005
Carcass weight, kg	77.6^{a}	81.5^{ab}	83.3^{b}	1.88	3.6	0.036
Lean meat content, %	58.5	58.6	58.8	0.50	0.1	0.891
Dressing percentage	73.5^{a}	74.3^{ab}	76.0^{b}	0.66	4.4	0.018
Lean meat in carcass, kg	45.5^{a}	47.7^{ab}	48.8^{b}	1.16	4.4	0.020

or vaccinated entire male pigs), except for lean meat content and dressing percentage. The YxH pigs had significantly higher lean meat content (59.7%) than the YxD pigs (57.6%) ($P = 0.003$, SE = 0.50%, F = 10.2) but lower dressing percentage (73.8 and 75.3%, respectively; $P = 0.048$, SE = 0.57%, F = 4.1). Female pigs had lower lean meat content (58.2%) than vaccinated entire male pigs (59.1%) ($P = 0.020$, SE = 0.41%, F = 5.9) and lower dressing percentage (73.7 and 75.4%, respectively; $P = 0.007$, SE = 0.52%, F = 8.1).

Time budgets

Time spent doing nothing was most frequent among pigs in the control treatment (77.4%) and differed significantly from pigs in the chicory and red clover treatments (71.5 and 67.2%, respectively) ($P = 0.001$, SE = 1.547%, F = 10.9, $N = 36$ observations unless otherwise stated). The pigs spent on average 70.5 ± 6.0% (mean ± SD) of their time lying down. Pigs in the chicory and red clover treatments spent a significantly lower proportion of their time lying down (69.3 and 67.0%, respectively) than pigs in the control treatment (75.2%) ($P = 0.026$, SE = 1.98%, F = 4.6). There was no difference in time spent sitting between treatments (2.7, 2.6 and 2.4%, for chicory, red clover and control, respectively; $P = 0.920$, SE = 0.66%, F = 0.1). However, pigs in the chicory treatment tended to spend more time standing (27.9% of observation time) and pigs in the red clover treatment spent significantly more time standing (30.3%) than pigs in the control treatment (22.3%) ($P = 0.084$ for chicory vs. control; $P = 0.018$ for red clover vs. control, SE = 3.06%, F = 3.6), see Fig. 1.

Pigs in the chicory and red clover treatments spent significantly more time in the lying area (64.4 and 67.0%, respectively) than pigs in the control treatment (54.2%) ($P = 0.007$, SE = 2.63%, F = 6.6). Thus, they spent correspondingly significantly less time in the slatted area (35.6 and 33.1%, respectively) than pigs in the control treatment (45.8%) ($P = 0.007$, SE = 2.63%).

The time spent eating commercial feed did not differ between treatments (5.5, 6.3 and 5.3% for chicory, red clover and control, respectively) ($P = 0.405$, SE = 0.06%, F = 1.0). The frequency of drinking was also similar between treatments (1.2, 1.2 and 1.1%, for chicory, red clover and control, respectively) ($P = 0.984$, SE = 0.44%, F = 0.02), see Fig. 1.

There was no significant difference in time spent eating/rooting silage between pigs in the chicory and red clover treatments (4.3 and 4.7%, respectively; $P = 0.560$, SE = 0.70%, F = 27.0; $N = 24$ observations). Pigs in the chicory treatment tended to spend more time nosing/rooting on the pen floor (12.3% of observation time) and pigs in the red clover treatment spent significantly more time (14.5%) in this activity than pigs in the control treatment (7.6%) ($P = 0.095$ for chicory vs. control; $P = 0.019$ for red clover vs. control, SE = 2.67%, F = 3.5, $N = 36$ observations). Pigs in the chicory and red clover treatments spent a lower proportion of time biting pen fittings (1.1 and 1.5%, respectively) than pigs in the control treatment (3.8%) ($P = 0.001$, SE = 0.43%, F = 11.2, $N = 36$ observations), see Fig. 1.

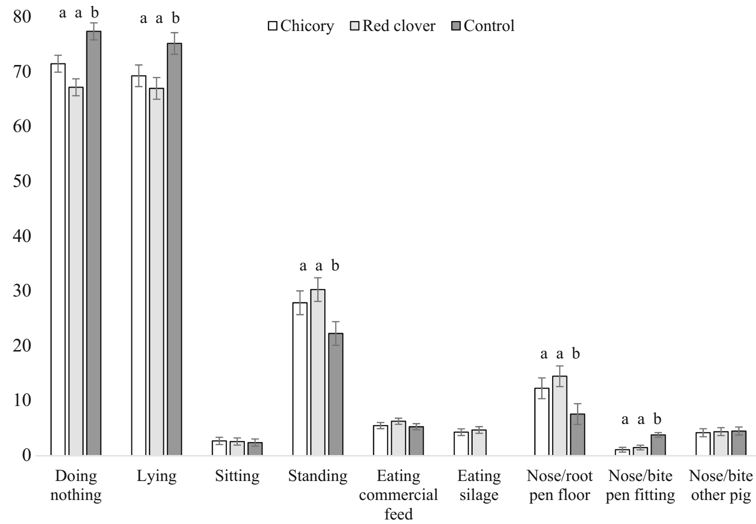

Fig. 1 Proportion (%) of time (least square means ± pooled standard error) spent on different behaviours by pigs in the chicory silage, red clover silage and control treatments. Treatment means with different superscripts are significantly different ($P < 0.05$). $N = 36$ except for eating silage, where $N = 24$

The proportion of time spent in different body postures (lying down, sitting and standing) did not differ between the first and second observation occasion (week 2 and week 4) ($P > 0.001$ for all). The pigs spent more time in the lying area in week 4 than in week 2 (67.1 and 56.6% of time, respectively) and correspondingly less time in the slatted area (32.9 and 43.4%, respectively; $P = 0.001$, SE = 1.71%, F = 43.8, $N = 36$ observations for both).

In week 4, the pigs spent more time (8.1% of time) eating commercial feed, i.e. with their snout in the feeding trough, than in week 2 (3.4%) ($P = 0.001$, SE = 0.46%, F = 52.4). However, among the pigs fed silage, the proportion of time spent eating silage did not differ between the observation occasions ($P = 0.690$). There was a slight tendency for a higher proportion of time spent nosing/biting on pen fittings in week 2 compared with week 4 (2.6 and 1.7%, respectively; $P = 0.078$, SE = 0.35%, F = 3.5). The proportion of time spent doing nothing, i.e. having the snout in the air, decreased over time (73.8% of time in week 2 compared with 70.3% in week 4; $P = 0.026$, SE = 1.15%, F = 6.0).

Social interactions

Differences between treatments as regards performance of social interactions are presented in Table 4. Nosing other pigs occurred more frequently among pigs in the control treatment than pigs in the chicory and red clover treatments ($P = 0.012$). Biting/nibbling tended to be performed to a greater extent among pigs in the control and chicory treatments than pigs in the red clover treatment ($P = 0.073$). Pigs in the chicory treatment also performed more head knocking behaviour than pigs in the control and red clover treatments ($P = 0.003$). The occurrence of other social interactions such as climbing, lifting, pushing and belly massaging did not differ between treatments ($P > 0.200$ for all). The frequency of rooting/eating silage among pigs in the chicory and red clover treatments did not differ ($P = 0.738$). Pigs in the control treatment were observed biting the pen fittings more frequently than pigs in the chicory and red clover treatments ($P = 0.002$).

There were no significant differences in the reactions of receiving pigs (i.e. avoiding an approach or returning an approach) between the different treatments ($P > 0.200$ for both). However, receiving pigs in the chicory treatment tended to respond with no reaction less often (12.4 times) than pigs in the red clover and control treatments (15.4 and 15.8 times, respectively) ($P = 0.080$, SE = 1.08 times, F = 2.9).

The number of social interactions by performing pigs did not differ over time ($P > 0.10$ for all) except for climbing, which occurred more frequently in week 4 than week 2 (0.96 times and 0.31 times, respectively; $P = 0.015$, SE = 0.21 times, F = 7.3). The reaction of receiving pigs was not influenced by observation occasion ($P > 0.10$ for all).

Discussion

This study investigated the effect of access to chicory and red clover silage on the performance, time budget

Table 4 Average number of social interactions per pig and observation occasion for pens in the chicory silage, red clover silage and control treatments. Total time of continuous observations was 1 h/pen (5 min × 3 times a day × 2 days on 2 occasions). Data are presented as least square means, pooled standard error (SE) and F-value. $N = 36$ observations. Treatment means within rows with different superscripts are significantly different ($P < 0.05$)

	Treatment					
	Chicory silage	Red clover silage	Control	SE	F-value	*P* value
Nosing	11.7^{b}	13.8^{b}	16.6^{a}	1.03	0.6	0.012
Bite/nibbling	1.3^{a}	0.5^{b}	1.7^{a}	0.35	2.6	0.073
Tail biting	0.10	0.18	0.38	0.13	1.2	0.139
Head knock	1.76^{b}	0.62^{a}	0.36^{a}	0.26	8.1	0.003
Climbing	0.55	0.81	0.54	0.31	0.2	0.788
Lifting	0.07	0.23	0.29	0.14	0.7	0.503
Pushing	1.19	1.76	0.95	0.33	1.6	0.230
Belly massage	0.04	0.25	0.06	0.11	1.2	0.324
Biting pen fitting	1.1^{b}	0.7^{b}	3.5^{a}	0.49	9.6	0.002

and social interactions of finishing pigs. Organic pig production can benefit from using ley crops, as inclusion of legumes in the crop rotation results in fixation of atmospheric nitrogen. Leys where several plant species are grown simultaneously also have a positive impact on biodiversity. Moreover, inclusion of nutritionally high-quality silage in the diet of growing/finishing pigs could increase the use of locally produced feed materials, replacing other protein sources, and result in more sustainable use of arable land (Hermansen et al. 2017). At the same time, the legal requirement on giving organic pigs' access to roughage can be fulfilled. This study was performed under experimental conditions and did not fulfil all the requirements for organic pig production, e.g. organically produced feed and access to outdoor areas, because we wanted to evaluate the influence of silage in a controlled study. However, the number of pigs per pen was less than in commercial systems, and the space allowance (1.44 m^2/pig) was similar to the organic requirement of 1.3 m^2/pig under EU organic regulations and 0.8–1.0 m^2/pig (for pigs of 80–110 kg live weight) under Swedish animal welfare law (EC 2008; SJVFS 2017). Overall, the results from the present study provide a better understanding of the benefits and disadvantages of feeding silage to finishing pigs.

Performance

Daily weight gain was lower in pigs in the chicory and red clover silage treatments than in pigs in the control treatment. The conventional feed allowance was 20% lower (on energy basis) in the silage treatments, and the lower weight gain indicates that the capacity of these pigs to consume and digest silage was too low to supply this nutrient deficit. Similar findings have been reported in previous studies (Edwards 2003; Hansen et al. 2006; Bikker et al. 2014; Wallenbeck et al. 2014). However, the growth rate was not as pronounced as expected based on the reduced energy allowance, which suggests that chicory and red clover silage contributed some energy and nutrients to the finishing pigs. Carlsson et al. (1999) concluded that clover-grass silage, and other roughage-based diets, are consumed well by pigs, give satisfactory digestibility values and can provide energy for growing pigs. In the present study, the pigs were supplied with intact silage ad libitum, although the exact amount of chicory and red clover silage consumed was not recorded. Previous studies have shown that both clover-grass and chicory forages are palatable and well consumed by pigs (Carlson et al. 1999; Ivarsson et al. 2012). Restricted feeding is believed to result in higher foraging motivation (Day et al. 1995; Beattie and O'Connell 2002). However, limited capacity for intake and hindgut fermentation of fibrous feedstuffs in young growing pigs can have a negative effect on performance (Edwards 2003). The low silage consumption in the present study may also have been due to warm weather, and corresponding high indoor temperatures, during the experimental period. Voluntary feed intake is affected by thermal environment factors such as air temperature and humidity (Bruce and Clark 1979; Verstegen et al. 1987; Massabie et al. 1997). Moreover, microbial hindgut fermentation of fibrous feedstuffs to produce short-chain fatty acids also produces heat which, together with high ambient temperatures, may have affected the intake of silage (Nyachoti et al. 2004). Stahly and Cromwell (1986) reported that dietary addition of 10% alfalfa meal depressed daily gain by only 1% in a cold environment (10 °C), compared with 3 and 5% in 22.5 and 35 °C environments, respectively.

In the present study, there were no substantial differences in the energy content and chemical composition of the two silages (Table 1). Pigs in the red clover treatment had numerically higher daily growth than pigs in the chicory treatment, which may indicate higher consumption of red clover silage. Moreover, feed conversion ratio based on commercial feed intake was lower for the pigs fed red clover than for those fed chicory and the control diet, which suggests that the red clover silage contributed some nutrients to the finishing pigs. Data on digestibility coefficients for forage crops are lacking, but in vitro and in vivo studies on the organic matter (OM) digestibility of different forms of forages (meal, fresh or silage) have reported digestibility values within the range 40–80% and have concluded that growing/finishing pigs have the capacity to digest roughage to some extent (Håkansson and Malmlöf 1984; Andersson and Lindberg 1997a, 1997b; Carlsson et al. 1999; Jørgensen et al. 2012). However, a number of factors would affect the digestibility value: choice of plant species, plant stage at harvest, dietary NDF content, whether the forage is dried, milled, chopped, ensiled or served fresh, and the ability of pigs to sort out more desirable parts such as leaves and stems (Andersson and Lindberg 1997b; Carlsson et al. 1999; Edwards 2003).

Inclusion of fibre-rich feed stuffs is often associated with increased gut fill and increased gastrointestinal organ weight (Pluske et al. 2003; Wellock et al. 2008). This in turn lowers the dressing percentage (Heyer et al. 2006; Bikker et al. 2014; Wallenbeck et al. 2014). Dressing percentage of pigs in the chicory and the red clover treatments in the present study was numerically lower (by 2.5 and 1.7 percentage units, respectively) than for pigs in the control, although the difference was only significant between the chicory treatment and the control. However, the NDF content of the chicory and red clover silages in this study was similar and, because actual silage consumption was not recorded, it is difficult to explain this result. Ivarsson et al. (2012) found that inclusion of chicory forage stimulated hindgut development and resulted in a heavier colon, which might explain the lower dressing percentage among pigs in the chicory treatment. The lower dressing percentage might be the reason for the significantly lower carcass weight found among these pigs. As shown in other studies (Danielsen et al. 1999; Hansen et al. 2006; Bikker et al. 2014; Wallenbeck et al. 2015), lean meat content was not affected by the dietary treatment. Any energy intake above maintenance and beyond the required level for maximum protein deposition will be used for lipid synthesis (Van Milgen et al. 2000). However, the pigs in the chicory and red clover treatments did not exceed the maximum protein deposition and thus energy was not used for lipid synthesis and fat deposition. These pigs probably did not consume enough feed to fulfil their energy requirement, resulting in poorer growth than in pigs in the control treatment.

Time budgets

It is well established that pigs of modern breeds housed indoors in pens are inactive, lying down resting and sleeping for most of the day (Morrison et al. 2007). This was also found in the present study, with an inactivity level of 70% on average. The experimental period had very warm summer weather and the ventilation system did not manage to cool the finishing unit sufficiently, so the indoor temperature was not as low as desirable. This might have affected the proportion of inactive time among the pigs. While the activity level in pigs kept indoors is low, it has been shown that various rooting materials can increase their exploratory behaviour to differing degrees (Beattie et al. 1996; Olsen et al. 2000; Guy et al. 2002a, 2002b; Long 2002; Olsen et al. 2002). Jensen and Pedersen (2007) concluded that straw is a good rooting material, but that some other materials are preferred by pigs. Foraging behaviour is stimulated when the enrichment material is also edible (Studnitz et al. 2007). According to Olsen et al. (2000), pigs prefer roughage with a low DM content and the amount of time pigs spend manipulating roughage depends on the specific characteristics of the roughage offered, such as DM content, complexity, texture, smell and taste. In the present study, pigs with access to silage were more active and spent less time lying down than pigs in the control treatment without silage. As shown previously by Høøk Presto et al. (2009) and Presto et al. (2013), access to silage stimulated the pigs to be more active than when only straw was provided as an enrichment (control treatment). The pigs provided with chicory and red clover silage spent a higher proportion of their time in the pen lying area and up to twice as much time nosing/rooting on the pen floor than the pigs in the control treatment. This was probably because the silage racks were placed in the lying area and some of the silage ended up on the pen floor when the pigs were eating, which indicates that the pigs spent time exploring the silage on the floor.

The higher activity level and the lower proportion of time spent biting at pen fittings among pigs in the chicory and red clover treatments than pigs in the control treatment suggest that access to silage motivated the pigs to perform foraging and rooting behaviour.

Social interactions

There were fewer behaviours directed at other pigs and pen fittings among the pigs provided with silage. Pigs deprived of opportunities to forage and explore their surroundings may redirect those behaviours towards other pigs in the pen and pen fittings (Lyons et al. 1995; Beattie et al. 2000; Presto et al. 2013). In agreement with this, performing behaviour such as nosing at other pigs also occurred less frequently among pigs in the chicory and red clover treatments than pigs in the control. Taken together with the fact that the pigs in the silage treatments also spent more time nosing/rooting on the pen floor and less time on biting pen fittings (both regarding time budgets and social interactions), this indicates that the roughage occupied the pigs. Several studies have concluded that provision of straw and other rooting materials reduces unwanted and aggressive behaviours (Beattie et al. 2000; Kelly et al. 2000; Beattie et al. 2001; Olsen 2001; Guy et al. 2002b; Long 2002; Olsen et al. 2002; Bolhuis et al. 2005). However, as found by Olsen et al. (2000) and Høøk Presto et al. (2009), in the present study, providing access to silage seemed to stimulate the pigs even more than providing straw only.

The pigs in the chicory treatment performed more head knocking behaviour than those in the other two treatments. This was unexpected and could relate to those pigs being more unsatisfied due to hunger, as suggested by Jensen and Pedersen (2010). The general impression among the staff was that there were more silage residues in pens where pigs were fed chicory silage. However, those pigs spent a similar proportion of time eating/rooting silage as the pigs fed red clover silage. Numerically, pigs fed chicory silage had the poorest daily growth of all treatments, which might suggest that they did not fulfil their energy and nutrient requirements and thus felt hunger.

Conclusions

Finishing pigs fed 80% commercial cereal-based feed (energy basis) and chicory or red clover silage ad libitum showed lower daily weight gain than pigs in a control group fed 100% commercial cereal-based feed (100% of nutrient recommendation). Conversion of the commercial cereal-based feed to lean meat growth was more efficient for pigs fed red clover silage than pigs fed chicory silage and pigs fed only commercial feed (control), indicating that the pigs utilised the nutrients in clover silage. Moreover, pigs fed chicory or red clover silage were more active and performed more feed-directed behaviours and less behaviours directed towards other pigs and pen fittings, i.e. expressed more natural behaviour. Provision of a silage supplement can thus meet the goal in organic production of further improving animal welfare. There is potential to use silage as a locally produced feedstuff for finishing pigs, but a better understanding is needed of nutrient intake, feeding strategies and production systems that promote utilisation of silage in pig production.

Acknowledgements This study was part of the Core Organic ICOPP project, the Swedish component of which was funded by the Swedish Research Council for Environment, Agricultural Science and Spatial Planning (Formas). The authors are grateful to the staff at the Swedish Livestock Research Centre, SLU, Uppsala, for their work with the pigs in the experiment and the laboratory staff at the Department of Animal Nutrition and Management, SLU, for their work with the experimental chemical analyses.

Compliance with ethical standards The study was approved by the Uppsala Ethics Committee on Animal Research (ethics approval number C86/14), which is in compliance with EC Directive 86/609/EEC on animal experiments.

Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

References

Andersson C, Lindberg JE (1997a) Forages in diets for growing pigs 1. Nutrient apparent digestibilities and partition of nutrient digestion in barley-based diets including lucerne and white-clover meal. Anim Sci 65:483–491

Andersson C, Lindberg JE (1997b) Forages in diets for growing pigs 2. Nutrient apparent digestibilities and partition of nutrient digestion in barley-based diets including red-clover and perennial ryegrass meal. Anim Sci 65:493–500

Andersson K, Schaub A, Lundström K, Thomke S, Hansson I (1997) The effects of feeding system, lysine level and gilt contact on performance, skatole levels and economy of entire male pigs. Livest Prod Sci 51:131–140

Beattie VE, O'Connell NE (2002) Relationship between rooting behaviour and foraging in growing pigs. Anim Welf 11:295–303

Beattie VE, Walker N, Sneddon IA (1996) An investigation of the effect of environmental enrichment and space allowance on the behaviour and production of growing pigs. Appl Anim Behav Sci 48:151–158

Beattie VE, O'Connell NE, Moss BW (2000) Influence of environmental enrichment on the behaviour, performance and meat quality of domestic pigs. Livest Prod Sci 65:71–79

Beattie VE, Sneddon IA, Walker N, Weatherup RN (2001) Environmental enrichment of pig housing using spent mushroom compost. Anim Sci 72:35–42

Bikker P, Binnendijk G, Vermeer H, van der Peet-Schwering C (2014) Grass silage in diets for organic growing-finishing pigs. In G. Rahmann & U. Aksoy (eds.) 4th ISOFAR scientific conference (Istanbul, Turkey: IFOAM [International Federation of Organic Agriculture Movements]) pp. 815–818

Bolhuis JE, Schouten WGP, Schrama JW, Wiegant VM (2005) Behavioural development of pigs with different coping characteristics in barren and substrate-enriched housing conditions. Appl Anim Behav Sci 93:213–228

Bruce JM, Clark JJ (1979) Models of heat production and critical temperature for growing pigs. Anim Prod 28:353–369

Carlson D, Lærke HN, Poulsen HD, Jørgensen H (1999) Roughages for growing pigs, with emphasis on chemical composition, ingestion and faecal digestibility. Acta Agric Scand Sect A Anim Sci 49:129–136

Chai WH, Udén P (1998) An alternative oven method combined with different detergent strengths in the analysis of neutral detergent fibre. Anim Feed Sci Technol 74:281–288

Crawley K (editor) (2015) Fulfilling 100% organic pig diets: Feeding roughage and foraging from the range. ICOPP-Technical Note 4. Organic Research Centre, UK: ICOPP Consortium 2015. http://orgprints.org/28088/7/28088.pdf

Danielsen V, Hansen LL, Møller F, Bejerholm C, Nielsen S (1999) Production results and sensory meat quality of pigs fed different amounts of concentrate and ad lib. Clover grass or clover grass silage. Proceedings from NJF-seminar No. 303, Horsens, Denmark 16–17 September 1999 pp: 79–86

Day JEL, Kyriazakis I, Lawrence AB (1995) The effect of food deprivation on the expression of foraging and exploratory behaviour in the growing pig. Appl Anim Behav Sci 42:193–206

EC (2008) Commission regulation (EC) No 889/2008 of 5 September 2008 laying down detailed rules for the implementation of Council Regulation (EC) No 834/2007 on organic production and labelling of organic products with regard to organic production, labelling and control

Edwards S (2003) Intake of nutrients from pasture by pigs. Proc Nutr Soc 62:257–265

EFSA (2007) The risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems _ scientific opinion of the panel on animal health and welfare. EFSA journal, 611, 1_13

EU (1984) Commission Directive of 20 December 1983 amending Directives 71/393/EEC, 72/799/EEC and 78/633/EEC establishing community methods of analysis for the official control of feeding stuffs. Official Journal of the European Communities L 15/28, 18/1/1984

Foster L (1988) Herbs in pasture, development and research in Britain 1850–1984. Biol Agric Hortic 5:97–133. https://doi.org/10.1080/01448765.1988.9755134

Guy JH, Rowlinson P, Chadwick JP, Ellis M (2002a) Behaviour of two genotypes of growing-finishing pig in three different housing systems. Appl Anim Behav Sci 75:193–206

Guy JH, Whitehead N, Cussins RA (2002b) The pig mobile: a simple environmental enrichment device for growing pigs in barren pens. Proc 36th Int Congr of the ISAE. Egmond aan Zee, The Netherlands, p. 142

Håkansson J, Malmlöf K (1984) The nutritive value of grass-, clover- and pea-crop meals for growing pigs. Swed J Agric Res 14:45–51

Hansen LL, Claudi-Magnussen C, Jensen SK, Andersen HJ (2006) Effect of organic pig production systems on performance and meat quality. Meat Sci 74:605–615. https://doi.org/10.1016/j.meatsci.2006.02.014

Hermansen JE, Jørgensen U, L rke PE, Manevski K, Boelt B, Krogh Jensen S, Weisbjerg MR, Dalsgaard TK, Danielsen M, Asp T, Amby-Jensen M, Sørensen CAG, Vestby Jensen M, Gylling M, Lindedam J, Lübeck M, Fog E (2017) Green biomass – protein production through bio-refining. DCA report no. 093. Danish Centre for food and agriculture, Aarhus University

Heyer A, Andersson HK, Lundstrom K (2006) Performance, carcass and technological meat quality of pigs in indoor and outdoor production systems. Acta Agric Scand Sect A Anim Sci 56:55–64

Høøk Presto M, Algers B, Persson E, Andersson HK (2009) Different roughages to organic growing/finishing pigs — influence on activity behaviour and social interactions. Livest Sci 123:55–62 https://doi.org/10.1016/j.livsci.2008.10.007

Ivarsson E (2012) Chicory (chichorium intybus L) as fibre source in pig diets. Effects on digestibility, gut microbiota and performance. Doctoral thesis, Uppsala: Swedish University of Agriculture Science. Online: http://pub.epsilon.slu.se/8693/1/ivarsson_emma_120416.pdf

Ivarsson E, Liu HY, Dicksved J, Roos S, Lindberg JE (2012) Impact of chicory inclusion in a cereal-based diet on digestibility, organ size and faecal microbiota in growing pigs. Animal 6(07):1077–1085

Jennische P, Larsson K (1990) Traditionella svenska analysmetoder för foder och växtmaterial Rapport 60 Uppsala, Sweden SLL

Jensen MB, Pedersen LJ (2007) The value assigned to six different rooting materials by growing pigs. Appl Anim Behav Sci 108:31–44

Jensen MB, Pedersen LJ (2010) Effects of feeding level and access to rooting material on behaviour of growing pigs in situations with reduced feeding space and delayed feeding. Appl Anim Behav Sci 123:1–6

Jørgensen H, Carlson D, Lærke HN (2012) Influence of forage inclusion in the diet on ileal and total tract digestibility. Am Soc Anim Sci 90:176–178

Kelly HRC, Bruce JM, English PR, Fowler VR, Edwards SA (2000) Behaviour of 3-week weaned pigs in straw-flow, deep strawand flatdeck housing systems. Appl Anim Behav Sci 68:269–280

Lindberg JE, Andersson C (1998) The nutritive value of barley-based diets with forage meal inclusion for growing pigs based on total tract digestibility and nitrogen utilization. Livest Prod Sci 56(1):43–52

Long J (2002) Woodchip bedding offers pig benefit. Farmers Weekly, November, 1 pp.

Lyons CAP, Bruce JM, Fowler VR, English PR (1995) A comparison of productivity and welfare of growing pigs in four intensive systems. Livest Prod Sci 43:265–274

Massabie P, Granier R, Le Devidich J (1997) Effects of environmental conditions on the performance of growing-finishing pigs. Proc 5th Int Symp livestock. Environment 2:1010–1016

Morrison RS, Johnston LJ, Hilbrands AM (2007) The behaviour, welfare, growth performance and meat quality of pigs housed in a deep-litter, large group housing system compared to a conventional confinement system. Appl Anim Behav Sci 103:12–24

Nordic Committee on Food Analysis (1976) Nitrogen. Determination in foods and feeds according to Kjeldahl. 3rd edn. Nordic standard 6. Statens Teknologiska Forskningscentral, Esbo

Nyachoti CM, Zijlstra RT, de Lange CFM, Patience JF (2004) Voluntary feed intake in growing-finishing pigs: a review of the main determining factors and potential approaches for accurate predictions. Can J Anim Sci 84:549–566

Olsen AW (2001) Behaviour of growing pigs kept in pens with outdoor runs I. Effect of access to roughage and shelter on oral activities. Livest Prod Sci 69:255–264

Olsen AW, Vestergaard EM, Dybkjaer L (2000) Roughage as additional rooting substrates for pigs. Anim Sci 70:451–456

Olsen AW, Simonsen HB, Dybkjær L (2002) Effect of access to roughage and shelter on selected behavioural indicators of welfare in pigs housed in complex environment. Anim Welf 11:75–87

Pluske JR, Black B, Pethick DW, Mullan BP, Hampson D (2003) Effects of different sources and levels of dietary fibre in diets on performance, digesta characteristics and antibiotic treatment of pigs after weaning. Anim Feed Sci Technol 107:129–142

Presto M, Rundgren M, Wallenbeck A (2013) Inclusion of grass/clover silage in the diet of growing/finishing pigs -influence on pig time budgets and social behaviour. Acta Agric Scand Sect A Anim Sci 63(2):84–92. https://doi.org/10.1080/09064702.2013.793734

SAS (2017) Statistical analysis systems (SAS) version 9.4. SAS Institute Inc., Cary www.sas.com

Sather AP, Jones SDM, Tong AKW, Murray AC (1991) Halothane genotype by weight interactions on pig meat quality. Can J Anim Sci 71(3):645–658

SJVFS (2017) Statens jordbruksverks föreskrifter och allmänna råd om djurhållning inom lantbruket m.m. Jönköping. SJVFS 2017:25 Saknr L106 (In Swedish)

Stahly TS, Cromwell GL (1986) Response to dietary additions of fiber (alfalfa meal) in growing pigs housed in a cold, warm or hot thermal environment. J Anim Sci 63:1870–1876

Studnitz M, Jensen MB, Pedersen LJ (2007) Why do pigs root and in what will they root? A review on the exploratory behaviour of pigs in relation to environmental enrichment. Appl Anim Behav Sci 107:183–197

Van Milgen J, Quiniou N, Noblet J (2000) Modelling the relation between energy intake and protein and lipid deposition in growing pigs. Anim Sci 71:119–130

Verstegen MWA, Henken AM, van der Hell W (1987) Influence of some environmental, animal and feeding factors on energy metabolism in growing pigs. In: Verstegen MWA, Henken AM (eds) Energy metabolism in farm animals, effects of housing, stress and disease. Kluwer Academic Publishers, Hingham

Wallenbeck A, Rundgren M, Presto M (2014) Inclusion of grass/clover silage in diets to growing/finishing pigs – influence on performance and carcass quality. Acta Agric Scand Sect A Anim Sci 64(3):145–153. https://doi.org/10.1080/09064702.2015.1006668

Wellock IJ, Fortomaris PD, Houdijk JGM, Wiseman J, Kyriazakis I (2008) The consequences of non-starch polysaccharide solubility and inclusion level on the health and performance of weaned pigs challenged with enterotoxigenic Escherichia coli. Br J Nutr 99:520–530