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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: IS0212
2. Project title: Sustainable systems for weaner management: AGEWEAN
3. Contractor organisation(s):
   University of Newcastle
   ADAS Consulting Ltd
   SAC
   Harper Adams University College
   Meat and Livestock Commission
4. Total Defra project costs (agreed fixed price): £ 1,386,137
5. Project: start date .... 01 July 2003
   end date .... 30 June 2007

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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Introduction

The immediate post-weaning period in pigs is often characterised by reduced and variable feed intake, digestive disorders and poor growth and development. These effects can be reduced or prevented by the use of antibiotic growth promoters (AGPs), copper sulphate and zinc oxide, but the routine use of AGPs in feed was banned in the EU from January 2006 and, due to concern over environmental impacts, dietary levels of inclusion of copper and zinc are limited by regulation and may be further reduced in the future. Weaning pigs at a later age, when their digestive systems are more mature, has been suggested as an approach to reduce the potential negative effect of the AGP ban on pig productivity and the study reported here was undertaken to evaluate the practical impact of this approach under British farm conditions. The overall objective was to investigate the effects of weaning age in both an indoor lactation environment and an outdoor lactation environment on lifetime health and performance of sows and their progeny and on the overall system cost of production and environmental impact.

Methods

Studies were carried out at 6 separate experimental sites, chosen to represent a range of diverse geographical locations and pig production systems in Britain. Four sites were used to provide results for indoor systems of production (total of 90 sows per weaning age treatment) and two sites were used to provide results from outdoor systems of production (total of 100 sows per weaning age treatment). Three weaning age treatments were applied: 4 weeks (weaned at 21-28 days of age), 6 weeks (35-42 days of age) and 8 weeks (49-56 days of age). On each site gilts were introduced to the experiment at the point of farrowing and were followed through four consecutive parities. All progeny were monitored to weaning, a minimum of 50% of progeny were monitored to 30kg live weight and a minimum of 25% of progeny were monitored to slaughter weight, when their carcass parameters were recorded. A parallel study on environmental impact of the three weaning ages was carried out under controlled experimental conditions to measure effects on manure/slurry volume and composition and ammonia emissions.

Results

There were significant differences between the weaning age treatments in feed intake, daily liveweight gain (DLWG) and feed conversion ratio (FCR) during the immediate post-weaning period (weaning-30kg), with those pigs weaned at 8 weeks performing better than pigs weaned at 4 or 6 weeks of age. In addition, pigs weaned at 8 weeks of age appeared to have a more favourable gut flora, as indicated by log lactobacilli:log coliform ratios from faecal culture, than the pigs weaned at younger ages. Conversely, from 30kg to the point of slaughter, pigs weaned at 4 weeks of age had significantly higher DLWG than pigs weaned at 6 or 8 weeks of age, due to a significantly higher feed intake. Whilst there was no significant effect of weaning age on the number of pigs requiring veterinary treatments or the numbers of pigs that were removed or died whilst on trial during the individual grower phases, there was a significant increase in the number of 4 week weaned pigs dying or being removed from trial during the total period from weaning to slaughter. This was offset by numerically lower losses during the lactation period, such that no statistically significant lifetime difference occurred.

In terms of sow productivity, there was no effect of weaning age treatment on the total number of piglets born alive or dead, nor on the total numbers of piglets weaned over 4 parities. However, because of the extended lactation period, when the number of pigs produced per sow day on trial was extrapolated, it was calculated that those sows weaned at 8 weeks would produce, on average, 4 less piglets per year than sows weaned at 4 weeks of lactation. There was no effect of weaning age on the total number of sows that were removed for health reasons or died whilst on trial.

In the detailed study of environmental impact there was no effect of weaning age on daily ammonia emissions, and the results of this study suggested that increasing weaning age would not increase the nitrogen load per litter to the environment. However, the lower number of litters per sow with later weaning needs to be taken into account in overall calculations. Calculations from data collected in the larger systems study, based on the measured feed use and composition for both breeding and growing pigs, indicated that pigs weaned at 8 weeks of age required over 10g more phosphorus and over 500g more nitrogen from feed inputs to reach slaughter weight when compared to 4 week weaned pigs.

When total cost of production was modelled for different production systems (indoor slatted, indoor straw-based or outdoor), pigs weaned at 4 weeks of age had a lower cost of production in all systems in comparison to 6 or 8-week weaning (by approximately 3p/kg carcass weight at 2007 costs).

Conclusion

Under current UK conditions, and with appropriate nutrition and management, later weaning of piglets at 6 or 8 weeks of age offers no significant benefits for health or performance of the progeny which outweigh the reduction in sow output when compared to the current industry norm of 4 week weaning. Both economic and environmental evaluations indicated best efficiency for the 4 week system.

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:
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   - details of methods used and the results obtained, including statistical analysis (if appropriate);
   - a discussion of the results and their reliability;
   - the main implications of the findings;
   - possible future work; and
   - any action resulting from the research (e.g. IP, Knowledge Transfer).

RATIONALE FOR PROJECT

The immediate post-weaning period in pigs is often characterised by a reduced and variable food intake and poor growth and development, reducing lifetime performance. This may be accompanied by a reduction in the ability of the digestive tract to absorb and utilise nutrients, which in turn leads to an increased nutrient load to the environment. Historically, the severity of the post-weaning growth check has been reduced by the use of in-feed antibiotic growth promoters (AGPs), copper sulphate and zinc oxide to stabilise gut microbiology, reduce disease risk, enhance the efficiency of feed conversion and hence maximise nutrient capture. However, from 1 January 2006 the routine use of in-feed AGPs has been banned and, due to concern over environmental pollution, levels of inclusion of heavy metals for enteric pathogen control may well be further limited in the future. Weaning pigs from the sow at an older age, when their digestive systems and immune function are more mature, has been suggested as an approach to reduce the potential negative effect of the AGP ban on the national herd. The objective of the AGEWEAN programme of research was to investigate the effects of weaning age (4, 6 or 8 weeks), in both an indoor and outdoor lactation environment, on biological and economic efficiency of a pig production system where diets contain no AGPs and lower levels of copper and zinc.

SCIENTIFIC OBJECTIVES

The overall objective was to investigate the effects of weaning age in both an indoor lactation environment and an outdoor lactation environment on lifetime performance and the cost of production, environmental impact, food safety and gut biology.

The individual components of this were to:

1) Assess the effect of weaning age on piglet lifetime performance (growth rate and efficiency of nutrient capture) in an indoor lactation environment and an outdoor lactation environment.
2) Assess the effect of weaning age on sow performance (fertility and efficiency of nutrient capture) in an indoor lactation environment and an outdoor lactation environment.
3) Assess the effect of weaning age on gut health, gut microflora and the presence of zoonotic organisms in an indoor lactation environment and an outdoor lactation environment.
4) Assess the effect of weaning age on slurry volume and composition and ammonia emissions.
5) Construct a whole system model for resource (nutrient, energy, finance) budgeting under different weaning age and environment scenarios

PROJECT OVERVIEW AND GENERAL METHODOLOGY

The overall project design was for two parallel studies which investigated, at the whole system level, the effect of a range of weaning ages in indoor and outdoor lactation environments. These studies were used to produce performance, health and nutrient balance data for systems adopting the different weaning ages (Objectives 1-3). A third parallel study made direct measurements of the environmental impact of systems adopting different weaning ages by measuring manure volume and composition, and gaseous emissions (Objective 4). The information arising from these objectives was then used in a financial modelling exercise (Objective 5). Meetings of the project consortium and sponsors were held quarterly to agree protocol details, review progress and report findings to date.

The farm system studies (Objectives 1-3) were initially distributed across 5 indoor and 2 outdoor units, chosen to represent diverse geographical locations within Britain and different types of production system typically seen within the national herd. Each site carried out a contemporary comparison of three weaning ages (4, 6 or 8 weeks) according to standard protocols. Following discussions within the steering group, and between the subcontractor and Defra, one indoor site was withdrawn from the study as a result of animal health and staffing problems which resulted in very poor pig performance and loss of experimental data. All other sites completed the protocols according to plan. The four indoor sites provided a total of 90 sows per weaning age treatment, and the two outdoor sites provided a further 100 sows per weaning age treatment. The three weaning age treatments were:

- 4-week weaning – animals weaned at between 21 and 28 days to conform to the most liberal interpretation of EU Directive 2001/93, with sites operating an all-in, all-out weekly batch management system.
- 6-week weaning – animals weaned between 35 and 42 days of age
- 8-week weaning – animals weaned between 49 and 56 days of age.

On any given experimental site, contemporary gilts were allocated at random to the three different treatments at the point of first farrowing and were then followed through 4 consecutive parities, remaining on the same weaning age treatment throughout. All progeny were recorded until the point of weaning, a minimum of 50% of litters per weaning age treatment per parity per site were recorded to 30kg liveweight, and a minimum of 25% of litters were similarly recorded through to slaughter weight to provide data on lifetime performance. In order to achieve an agreed number of experimental replicates for evaluation of effects on feed efficiency, sites with large pen groups allocated more litters if necessary. All sows and progeny were weighed at defined points in the production cycle (see results) and all feed inputs were weighed and recorded. Data were also collected at each site on resource inputs (bedding, water, power, labour) to inform the final modelling process.

Housing and Husbandry

The type of housing varied between sites but in all cases conformed to all welfare requirements under EU Directive 2001/93. In the indoor production systems, both straw-based and slatted-floor systems were included, the system being common to all experimental treatment groups within any individual site. On the indoor production sites, any sow allocated to either the 6-week or 8-week weaning treatment was not confined in a traditional farrowing crate for more than the first 4 weeks of her lactation, but was loose housed with her litter in a single pen for the final weeks of lactation.

In the outdoor production system all sows farrowed and lactated outside. On one site the progeny were transferred to indoor accommodation after weaning, whereas the other site finished pigs in outdoor kennels.

Provisions were made to treat pigs in the event of serious health problems. Any individual pig could be treated where necessary, but batch treatment of a cohort of pigs was only permitted when an agreed proportion of pigs showed symptoms of disease.

Progeny which were monitored to slaughter weight were marketed according to the optimum slaughter weight for the commercial contract in place at each individual site, typically at 90-100 kg liveweight. Standard commercial carcass grading data were collected.

Diets

Diets were designed to be appropriate for the age/weight and production stage of the pigs. They were purchased from the supplier of choice for each site, but had to conform to an agreed project specification range decided in advance by the project steering group following discussion with commercial nutrition consultants (detailed in the full final report). No diet contained any antimicrobial growth promoters (AGPs) or zinc or copper supplements at levels at which they would be considered to act as growth promoting agents (levels were <25ppm added copper and <100ppm added zinc). Compliance with this was checked by analysis of feed samples from all sites.

All pigs received creep feed from one week of age on indoor sites and from four weeks of age on outdoor sites. This was the same diet as was offered immediately following weaning. Whilst diets in the post weaning phase differed between treatments, according to weaning age, the subsequent grower and finisher diets were common to all treatments within any site.

Samples were taken of each batch of feed delivered to each site. These were bulked quarterly for each diet, and analysed for nitrogen and phosphorus content to enable overall efficiency of nutrient use to be estimated.

Health Monitoring

In addition to the recording of all deaths, removals to hospital accommodation and veterinary treatments, faecal samples were taken from a sample of 4 piglets per treatment per parity per site at 4-5 days postweaning. The faeces collected were cultured to measure log lactobacilli: log coliform ratio (L:C ratio) which was used as an index of gut health; a high L: C ratio indicating a gut which is considered to be better adapted to resist pathogen challenge.

Data Analysis

All data analyses were carried out by BIOSS using Genstat for Windows (7th edition). The data were analysed for all six sites combined, and also for the indoor and outdoor herds separately. In tables of results, the treatment means are shown, together with the standard error of difference and significance of the weaning age effects over all sites. No comparison between indoor and outdoor herds was made, since this would not be statistically valid given non-random selection and limited replication. The objective was to assess the generality of weaning age effects across production systems.

The number of veterinary treatments and the number of removals and deaths were expressed as numbers per 100 pigs (or per 100 sows) for each combination of site and weaning age, and these figures were analysed using

Friedman's non-parametric analysis of variance. Data in the form of counts (e.g. numbers born alive) were analysed using generalized linear mixed models, and data on most other variables were fitted using linear mixed models. Weaning age and parity were treated as fixed effects, whilst site and its interactions with weaning age and parity were taken as random effects. The numbers of litters per sow were analysed using ordinal regression analysis with weaning age and site as fixed effects.

RESULTS

Results are summarised in this overview as the combined results for all four parities. Separate results from each parity are available in the more detailed final project report.

Objective 1. Assess the effect of weaning age on piglet lifetime performance (growth rate and efficiency of nutrient capture) in an indoor lactation environment and an outdoor lactation environment.

Suckling period

The mean sow lactation feed use, creep feed consumption and weaning weight are shown in Table 1 for each weaning age treatment. Creep feed intake of 4-week weaned litters was minimal, but intake increased greatly as weaning age progressed. Values for the later weaned litters are probably under-estimates, since piglets were observed to eat sow feed on many of the sites.

Table 1 – Progeny Performance in the suckling period

	Indoor			Outdoor		
	4-wk	6-wk	8-wk	4-wk	6-wk	8-wk
Lactation feed (kg/pig weaned)	18.45	29.27	42.42	20.97	36.74	52.91
Creep feed intake (kg/litter)	3.05	11.53	37.23	-	15.83	45.61
Wean Wt (kg)	8.10	11.69	16.99	7.72	11.93	17.05

‡ No sed is shown, because data were not normally distributed.

Weaning to 30kg

From weaning until 30kg those pigs weaned at 8 weeks of age consumed significantly more feed per day and showed significantly higher daily live weight gains (Table 2). However pigs weaned at four weeks of age had significantly better pen feed conversion ratios, probably as a result of the more digestible, higher nutrient density diets they were offered during the immediate post-weaning period.

When pre and post-weaning growth data were combined, and daily live weight gain between birth and 30kg was calculated, there were no significant differences between pigs weaned at 4 or 8 weeks of age. However, overall, those pigs weaned at 6 weeks of age showed significantly lower live weight gains during this period, although the absolute difference was small.

Table 2 – Progeny Performance from weaning to 30 kg

	Indoor			Outdoor			Overall wean age effect	
	4-wk	6-wk	8-wk	4-wk	6-wk	8-wk	sed	P
Wean – 30kg								
DLWG	0.447	0.475	0.553	0.515	0.573	0.653	0.007	<0.001
Feed/pig/day	0.735	0.823	0.961	0.857	0.982	1.094	0.013	<0.001
FCR	1.67	1.77	1.78	1.68	1.74	1.70	0.023	<0.001
Birth - 30kg								
DLWG	0.387	0.377	0.394	0.431	0.434	0.426	0.004	<0.05

30kg to Slaughter

Although pigs from all treatments on each unit experienced the same housing and diets over this phase, there was a significant effect of weaning age on the mean daily live weight gain of pigs from 30kg to the point of slaughter. Pigs weaned at 4 weeks of age consumed more feed and had a significantly higher rate of gain than those weaned at 6 or 8 weeks of age (Table 3). There were no significant effects of weaning age on feed conversion ratios. Weaning age had a significant effect on carcass backfat thickness (mm P_2) at the time of slaughter, with pigs weaned at 4 weeks of age having a significantly higher level of back fat when compared to pigs weaned at 6 or 8 weeks of age.

Lifetime growth rates were calculated for all pigs that were monitored to slaughter weight. Whilst all pigs showed a similar mean growth rate of approximately 0.6kg/day from birth to slaughter, those pigs weaned at 6 weeks of age had significantly lower daily live weight gains than pigs weaned at 4 or 8 weeks of age.

Table 3 – Progeny Performance from 30 kg to slaughter

	Indoor			Outdoor			Overall wean age effect	
	4-wk	6-wk	8-wk	4-wk	6-wk	8-wk	sed	P
30kg - Finish								
DLWG	0.81	0.79	0.79	0.79	0.76	0.74	0.011	<0.05
Feed/pig/day	2.09	2.04	2.03	2.44	2.37	2.35	0.031	<0.05
FCR	2.62	2.62	2.63	3.28	3.28	3.34	0.048	ns
Lifetime								
P_2 at Slaughter	11.20	10.73	10.68	11.07	10.85	10.80	0.073	<0.001
DLWG	0.61	0.60	0.61	0.60	0.59	0.59	0.002	<0.01

Economic and environmental implications

The feed cost per weaner was obviously greater for the later weaning ages but, despite the different qualities and costs of diets used in the post-weaning phase, the overall lifetime feed cost per kg progeny liveweight gain (including all sow feed inputs) did not differ significantly between treatments (Table 6).

Nutrient budget calculations, based on overall feed inputs (eaten plus wastage) and diet analyses for each treatment, indicated that feed nitrogen and phosphorus inputs per kg pig produced were significantly greater for the later weaning ages, suggesting the potential for greater environmental impact.

Table 6 – Economic and nutrient efficiency of feed use (all values include sow diet inputs)

	Indoor			Outdoor			Overall wean age effect	
	4-wk	6-wk	8-wk	4-wk	6-wk	8-wk	sed	P
Feed cost (£)								
Per weaner	5.81	7.45	10.09	7.50	9.91	12.97	0.227	<0.001
Per kg lifetime gain	0.39	0.38	0.38	0.42	0.44	0.44	0.009	ns
Nutrient input (g/kg lwt produced)								
Nitrogen	78.6	81.1	82.5	81.5	81.1	89.2	1.74	<0.01
Phosphorus	1.44	1.48	1.52	1.49	1.50	1.65	0.032	<0.01

Objective 2. Assess the effect of weaning age on sow performance (fertility and efficiency of nutrient capture) in an indoor lactation environment and an outdoor lactation environment.

Sow Longevity

There were no significant differences between weaning age treatments with regards to the number of sows that were removed from trial. In total 143 sows were culled or died whilst on trial: 41 from the 4-week treatment, 46 from the 6-week treatment and 56 from the 8-week treatment (differences not significant). The main reasons for culling were sows returning to service on three occasions within the same parity (49 sows), leg problems (14 sows) and poor body condition (5 sows). Despite the very different lactation lengths, lactation loss in sow liveweight and backfat did not differ between treatments.

Reproductive performance

There were no significant effects of weaning age treatment on the lifetime total number of piglets born alive or born dead, number of piglets weaned or the number of litters produced per sow over her productive lifetime (maximum four parities).

In order to assess the effects of extending lactation on annual reproductive output, the number of piglets produced per sow day on trial (from first farrowing until fourth parity weaning, or culling) was calculated. There was a very significant effect of weaning age on this parameter, which was equivalent to the 4-week weaned sows producing approximately 4 more piglets per year than the 8-week weaned sows.

Table 5 – Sow lifetime performance (maximum of 4 trial parities)

	Indoor			Outdoor			Overall wean age effect	
	4-wk	6-wk	8-wk	4-wk	6-wk	8-wk	sed‡	P
Total number born	43.2	41.4	40.8	43.8	44.4	43.8		ns
Total weaned	34.7	33.7	31.2	32.3	32.3	30.3		ns
Litters produced	3.52	3.41	3.31	3.68	3.68	3.54		ns
Pigs per 100 sow days on trial	7.8	7.4	6.9	7.2	6.5	5.8	0.19	<0.001

‡Where no sed is shown, this is because analyses were carried out on transformed data and back transformed means are presented.

Data from the breeding herd on efficiency of nutrient capture were incorporated into the progeny analysis (see Objective 1) and data economic consequences of productivity were incorporated into the economic modelling studies (see Objective 5).

Objective 3. Assess the effect of weaning age on gut health, gut microflora and the presence of zoonotic organisms in an indoor lactation environment and an outdoor lactation environment.

Pigs weaned at 8 weeks of age had a significantly higher log lactobacilli:log coliform ratio than pigs weaned at 4 or 6 weeks of age, indicating a more favourable gut microflora (Table 4). However, when analysed separately for each growth stage, there were no significant effects of weaning age on the number of veterinary treatments, removals or deaths. Despite the absence of AGPs, and the fact that herds varied in background health status, the prevalence of losses was lower than BPEX Pig Yearbook national herd averages. When cumulative lifetime effects of weaning age were investigated, those pigs weaned at 4 weeks of age were significantly more likely to die or be removed from trial than pigs weaned at 6 weeks or 8 weeks of age. However, when the complete lifetime results (birth to slaughter) were considered, no significant differences between treatments in health parameters were apparent. A relatively high pre-weaning mortality in the outdoor sample was partially attributable to a serious problem of fox predation at one site.

Table 4 – Progeny health

	Indoor			Outdoor			Overall wean age effect	
	4-wk	6-wk	8-wk	4-wk	6-wk	8-wk	sed‡	P
Faecal L:C ratio after weaning	1.22	1.17	1.27	1.11	1.18	1.28	0.029	<0.001
Wean - finish								
Treatments per 100 pigs	3.8	3.1	1.8	0.5	0.1	0.1		ns
Deaths+ removals per 100 pigs	5.8	4.8	4.3	5.5	3.4	3.1		<0.05
Lifetime								
Treatments per 100 pigs	6.4	5.3	5.3	1.1	0.7	0.3		ns
Deaths + removals per 100 pigs	18.3	19.9	20.4	28.1	26.0	27.0		ns

‡Where no sed is shown, this is because non parametric analyses were carried out.

Analysis of caecal content samples taken from 360 pigs per weaning age treatment, systematically distributed across the sites and parities, showed no effect of weaning age on the prevalence of salmonella positive samples. However, diaphragm meat juice samples showed a significantly higher prevalence of samples positive for antibodies to salmonella in outdoor 6 week weaned pigs, than in 4 or 8 week weaned pigs. There was no significant effect of weaning age on the mean lung scores for pneumonic lesions.

Objective 4. Assess the effect of weaning age on slurry volume and composition and ammonia emissions.

The objective of this independent study, carried out under controlled conditions at a single site (ADAS Terrington), was to assess the effect of weaning age on manure/slurry volume, and composition, and ammonia emissions under similar nutritional input conditions to the systems study.

Materials and Method

A randomised block design was used with four replicates over time from February 2004 to May 2005. There were three weaning age treatments: four (21-28 days), six (35-42 days) or eight (49-56 days) weeks of age, 4ww, 6ww and 8ww, respectively. Treatments were run simultaneously. A total of 36 first parity sows and their litters (Large White × Landrace × White Duroc) were studied. Pregnant gilts were randomly allocated to treatment (weaning age) prior to farrowing. The pregnant gilts were moved to the farrowing accommodation (one treatment per room) approximately one week prior to farrowing. They remained in this accommodation until weaning when they were moved to the weaned sow accommodation (one treatment per room) where they remained until 12 weeks post-farrowing. The piglets remained in the farrowing accommodation until 12 weeks post-farrowing, however, the creep area was only accessible during the lactation period up to weaning. Pigs were fed with diets that were all formulated without antibiotic growth promoters and with reduced levels of zinc (<100 ppm) and copper (<25 ppm). The liveweight of sows, their P2 backfat thickness (mm; P2 measurements taken at the last rib and 65 mm vertically down from the midline) and their condition score (1-5; 1=poor, 3=satisfactory and 5=obese) were recorded. The litter size at birth, with numbers, and weights, of piglets born alive, dead or mummified was recorded. A weighed amount of feed was offered daily to sows and piglets, and weekly feed intake was recorded for both. Samples of feed were analysed for dry matter (DM) and total nitrogen (N). Weekly water consumption was recorded using volumetric water meters (litres). Individual liveweight of piglets was recorded at birth, four, six, eight and 12 weeks of age. Records were kept of all animals requiring veterinary treatment detailing; date, animal ID, condition and treatment administered. The weight of straw added to, and the weight of manure removed from, the farrowing rooms, were recorded on a daily basis. Representative samples, of straw and manure, were collected over each replicate study period and analysed for DM, total N, ammonium-N, nitrate-N, phosphorus (P), and pH. The amount of slurry, removed from each treatment room, was recorded and samples analysed for DM, total N, ammonium-N, nitrate-N, phosphorus (P), and pH. Ammonia (NH_3) emissions were calculated on a weekly basis.

A repeated measures analysis was used to analyse the liveweight, P2 and body condition of sows with blocking on replicate, and weaning age acting as treatment. The numbers of piglets in a litter were used as covariates in some analyses. Analysis of variance was used to analyse all other data with blocking on replicate, and weaning age acting as treatment. Duncan's multiple range test was used for post-hoc analysis.

Results and Discussion

Performance

A total of 375 animals were born over the course of the study (360 alive, 11 dead, 4 mummified). The mean performance results, per litter, are given in Table 5. The 8ww sows produced smaller litters, although the difference was not significant. Removals from this treatment group had greater proportional impact on litter size and fewer piglets were weaned from the 8ww sows than the other weaning age treatment sows.

Table 5 - Mean number of piglets per litter

	4 week	6 week	8 week	SED	P value
Born alive	10.17	10.83	9.00	1.20	0.313
Born dead	0.17	0.42	0.33	*	*
Born mummified	0.25	0.08	0.00	*	*
Weaned	9.75[a]	9.96[a]	7.58[b]	0.56	<0.001

[ab]means within rows with different superscripts were significantly different (P=0.05); *insufficient data for analysis

There was no effect of weaning age treatment on the liveweight, body condition score or on backfat (P2) of sows. Weaning age treatment had a significant effect on piglet liveweight, with the 8ww piglets being heavier than the 4ww and 6ww piglets (mean liveweight per replicate for each treatment; 12.09, 12.08 and 13.77 kg for 4ww, 6ww and 8ww treatments respectively, SED=0.56, d.f.=2, P=0.007).

Health

There were few recorded incidences of sow illness either pre-weaning or post-weaning. Two sows were removed from the study as a result of ill health. One sow was removed from the 8ww treatment in replicate two, two days post-weaning, as a result of a burst abscess on the shoulder. Another sow was removed from the 6ww treatment in replicate three, 18 days post-farrowing, as a result of a gastric ulcer. There were few recorded instances of piglets requiring veterinary treatment pre-weaning. The majority of piglets requiring veterinary treatment post-weaning were treated for scour and were in the four and six week weaning treatments.

Feed and Water

The total amount of feed and water consumed by the piglets and sows on a per sow basis is presented in Table 6. Overall, the amount of feed and water consumed was similar for the three different weaning age treatment systems, suggesting that N excretion and ammonia emissions are unlikely to be greatly impacted by the treatments.

Table 6 - Total feed (kg) and water (l) consumed by piglets and sows over whole study per sow

	4 week wean	6 week wean	8 week wean
Feed (kg/sow)*	690.71	746.93*	743.14**
Water (l/sow)*	2364.30	2611.85*	2494.80**

* one litter effectively weaned at 18 days post farrowing due to sow illness; ** one sow removed at weaning due to illness

The composition of the diets offered during the study is presented in Table 7.

Table 7 - Composition of feed

	DM (%)	Total N (% as	CP*
Weaner 1	89.53	3.48	21.75
Weaner 2	89.08	3.54	22.13
Weaner 3	89.28	3.66	22.88
Grower	87.88	3.56	22.25
Dry sow	88.10	2.13	13.30
Lactation	87.08	2.71	16.88

* CP=Total N x 6.25

Straw and manure

The data in Table 8 show that treatment did not affect the total amount of straw used and manure (farm yard manure (FYM)) produced by the piglets and sows on a per sow basis. It should be noted that, after weaning, the sows were moved to separate fully slatted accommodation, and thereafter produced slurry only.

Table 8 -Total FYM (kg) and slurry (l) produced by piglets and sows over whole study per sow

	4 week wean	6 week wean	8 week wean
Straw (kg/sow)*	56.04	63.34*	61.94**
Manure (l/sow)	608.49	686.25*	699.41**

* one litter effectively weaned at 18 days post farrowing due to sow illness; ** one sow removed at weaning due to illness

The composition of the straw used and the manure produced is presented in Table 9. The N and P content of the straw was within the normal range. Total N content of the FYM was at the upper end of the normal range, but NH_4-N, at 26% of total N, was typical of fresh FYM (Anon, 2000).

Table 9- Composition of straw and FYM (replicate means)

	Straw	SD	FYM	SD
PH	6.55	0.97	6.65	0.97
DM (%)	87.88	3.31	24.03	3.50
ammonium N (kg/t)	0.04	0.04	2.86	1.71
nitrate N (kg/t)	0.05	0.03	0.01	0.001
total N (kg/t)	5.57	2.75	9.74	2.38
phosphorus (kg/t)	0.69	0.24	2.51	0.79

Slurry

The means of replicates for each treatment, for volume (litres) and the composition of slurry, collected from the time of sow entry into the farrowing accommodation to weaning, are presented in Table 10. There was no effect of weaning age on the mean volume of slurry produced pre-weaning. The total volume of slurry produced over the whole pre-weaning period, on a per sow basis, was 400.25, 540.82, and 499.36 (l/sow) for the 4ww, 6ww, and 8ww treatments, respectively (nb due to sow illness, only 11 sows completed the study for the 6ww and 8ww treatments). Slurry produced during this period resulted through seepage of liquid through the perforations in the plastic clips that were inserted into the slats and was of relatively low solids and nutrient content. Slurry N content at c. 3 kg/m^3 was fairly typical of such low DM content pig slurry (Anon, 2000).

Table 10 - Slurry volume and composition from sow entry into the farrowing accommodation to weaning.

	4 week wean	6 week wean	8 week wean	SED (d.f.=2)	P value
Volume (litres)	1254.0	1515.0	1409.00	679.1	0.929
pH	8.33	7.88	7.95	0.23	0.197
DM* (g/l)	16.10	36.60	20.40	12.71	0.304
ammonium N (kg/ m^3)	2.52	2.69	2.70	0.42	0.898
nitrate N (kg/ m^3)	0.28	0.27	0.17	0.09	0.499
total N (kg/m^3)	2.83	3.61	3.10	0.72	0.569
phosphorus (kg/m^3)	0.24	0.84	0.38	0.40	0.350

*Due to the dilute nature of slurry, slurry solids content expressed as g/l.

The means of replicates for each treatment, for volume (litres) and the composition of slurry, from weaning to 12 weeks post-farrowing, are presented in Table 11. Weaning age affected the mean volume of slurry produced in the post-weaning period to 12 weeks post farrowing, with more slurry being produced by the 4ww piglets and sows than the 6ww and 8ww treatment piglets and sows. The total volume of slurry produced over the whole post-weaning period, on a per sow basis was 811.33, 604.64, and 563.91 litres for the 4ww, 6ww, and 8ww groups, respectively. (nb due to sow illness, only 11 sows completed the study for the 6ww and 8ww treatments). The greater slurry production in the 4ww treatment reflects the longer period of time that these sows were housed in their post wean, fully slatted accommodation. Slurry N content was fairly typical and well within the expected range for dilute pig slurry, although the NH_4-N content, at 86-90% of total-N was high (Anon, 2000; Chambers, 2004a). There were no significant treatment effects on slurry composition. However, the P content for the 8ww treatment whilst low was within the upper and lower 10%ile range of pig slurry P analysis data (0.09 – 1.90 kg/ m^3) in recent studies (Chambers, 2004a).

Table 11- Slurry volume and composition from weaning to 12 weeks post farrowing.

	4 week	6 week	8 week	SED	P value
Volume (litres)	3983.0^b	3237^a	2710.0^a	242.6	0.006
pH litter	7.85	8.10	7.95	0.19	0.454
pH sow	7.98	7.62	7.97	0.33	0.509
DM* (g/l)	33.7	34.2	24.6	6.10	0.280
ammonium N (kg/ m^3)	4.76	5.04	4.37	3.58	0.256
nitrate N (kg/ m^3)	0.59	0.58	0.66	0.14	0.842
total N (kg/m^3)	5.55	5.56	4.96	0.40	0.309
phosphorus (kg/m^3)	0.56	0.44	0.26	0.19	0.365

** Due to the dilute nature of slurry, slurry solids content expressed as g/l.

Excretion

Slurry and manure, jointly represent major sources of ammonia emission in pig production and might, therefore, be considered together. There was no effect of weaning age treatment on excreted N (13.80, 14.34, 12.78, kg/sow; SED = 0.84, d.f.=2, P = 0.190; treatments 4ww, 6ww, and 8ww, respectively).

Ammonia emissions

The weekly ammonia emissions (g NH_3-N.lu^{-1}.wk^{-1}), where lu = livestock unit (1lu = 500kg liveweight), are presented in Table 12. At six weeks post-farrowing, there was a trend toward more ammonia being emitted from the 4ww system (P=0.067) than from the other weaning age systems. At eight weeks post farrowing, there was a significant effect of weaning age treatment on the weekly ammonia emission, with less ammonia being emitted from the 8ww systems compared with the 6ww systems. There were no other significant effects of treatment.

However, the amount of ammonia emitted per week increased the week after a group had been weaned. The post-weaning ammonia emissions remained higher than the pre-weaning emissions. This suggests that the increases in ammonia were associated with the change in housing at the time of weaning when the sows were moved to weaner accommodation, thereby increasing the emitting surface.

Overall there was no difference in the daily ammonia emissions per livestock unit with mean values of; 12.16, 12.81 and 10.30 g N / day / livestock unit for the 4ww, 6ww and 8ww treatments respectively (SED=2.13, d.f.=2, P=0.513). These estimates all compare quite favourably with (i.e. are lower than) the current emission factors in the UK Ammonia Emissions Inventory (Misselbrook *et al*, 2005) of c. 118, 185 and 185 g NH_3-N.lu^{-1}.wk^{-1}, for dry sows, farrowing sows (on straw or slats) and for weaners on straw, respectively.

Table 12- Ammonia emissions in grams per week per livestock unit[1] (g NH_3-N.lu^{-1}.wk^{-1})

Week	4 week wean	6 week wean	8 week wean	SED (d.f.=2)	P value
0	38.0	36.5	36.2	14.2	0.991
1	53.8	67.2	51.7	16.3	0.612
2	80.1	73.5	76.0	17.9	0.933
3	85.6	83.3	73.0	22.1	0.837
4	77.0	87.0	68.0	28.7	0.810
5	116.0	70.0	73.0	27.6	0.251
6	154.0	91.0	79.0	27.0	0.067
7	106.0	138.0	75.0	25.0	0.115
8	117.7[ab]	158.2[a]	77.2[b]	24.1	0.042
9	105.8	138.2	106.5	21.9	0.309
10	101.7	123.0	100.7	17.4	0.404
11	84.7	91.8	84.1	15.6	0.863
12	86.2	111.1	75.6	12.4	0.100

[ab]means within rows with different superscripts were significantly different (P=0.05); [1] 1 livestock unit = 500kg liveweight

The mean N content in the main study components; feed, N retention (growth), ammonia emission, and excreta (measured excretal N output and "derived" excretal N output) are presented in Table 13. There was no effect of weaning age treatment on the N content in the feed consumed, in that retained, in that excreted or in that emitted as ammonia. The "derived" estimates of N excretion are based on the total feed N intakes from which are deducted the outputs N in liveweight gain and NH_3-N emission, the difference representing excretal N (Smith *et al*, 2000). The difference in measured N excretion compared to the derived N excretion varied between 5% and 13% (based on N intake) across the treatments (Table 10). This inconsistency is probably largely due to the error associated with sampling and analysis of the slurry and, particularly the solid manure. The sampling errors and imprecision associated with manure analysis are well known and Chambers (2004b) reported a range in DM content of samples taken from heaps of pig FYM of 24–49%, with significant differences in the associated nutrient content. Research has also demonstrated the difficulty in homogenising manure samples even under laboratory conditions (Farrington, 2005). There are also problems associated with the rapid sedimentation of pig slurry and which can only be overcome with confidence by continual agitation during the sampling process. The apparent shortfall in N may also be a consequence of losses via denitrification as N_2 or N_2O, which in a straw-based FYM system have been estimated at c. 1% of total N (Hüther et al., 1997) or at 7-18% of total ammoniacal N (TAN) (Amon et al., 1997). Denitrification losses were not accounted for in this study.

Table 13- Nitrogen partitioning in components, feed, N retained in liveweight gain, ammonia and excreta, treatment means (kg N per replicate with 3 sows per replicate)

	4 week wean	6 week wean	8 week wean	SED (d.f.=2)	P value
Feed intake	61.6	57.2	56.8	5.96	0.683
Retained	18.47	16.05	17.17	2.08	0.543
Ammonia emitted	1.76	1.58	1.31	0.29	0.346
Excreta measured	33.6	36.8	32.3	3.20	0.412
Excreta derived[1]	41.4	39.5	38.4	3.97	0.750
Total N outputs measured	53.83	54.43	50.78		
Diff derived – measured excretal N as % N intake	12.6	4.8	10.7		

[1] Derived excretal N output by subtracting ammonia emission and retained N from the N intake in feed

Conclusions

There was no difference between weaning age treatments in the total amount of feed consumed. There was no effect of weaning age on daily ammonia emissions, but less NH_3-N was emitted by the 8ww system for at least part of the production cycle. However, there were fewer animals in this system in our study due to the removal of one sow and coincidentally smaller mean litters. The results of this study suggest that increasing weaning age will not increase the nitrogen load per litter to the environment. However, it is suggested that an eight week weaning system may require more breeding animals (to produce the same number of weaned pigs per unit time as the earlier weaning systems, to be validated) which will increase excretal N output and, therefore, increased potential for environmental emissions.

Objective 5. Construct a whole system model for resource (nutrient, energy, finance) budgeting under different weaning age and environment scenarios

Methods

Following on from the extensive data collected during the systems studies, a modelling exercise was carried out to estimate the inputs and costs of production of pigmeat under three different weaning age scenarios (4, 6 and 8 week weaning). Three different production systems were modelled, indoor production (characterised by kennelled dry sow housing and fully slatted housing for the progeny produced), indoor straw based production (deep straw bedded gestation accommodation and progeny housed in pens with a shallow covering of straw) and outdoor production (sows gestating and lactating outdoors, progeny housed outdoors until 30kg and then transferred to indoor finishing accommodation).

Existing spreadsheet-based models for sows (Cain and Guy, 2006) and weaner-finisher pigs (Bornett, Guy and Cain, 2003) were used to estimate the cost of production of pigmeat under 4, 6 or 8 week weaning systems. In these models, data on physical performance are combined with both variable and fixed costs to generate a cost of production for the different production systems (see Table 14 for a description of each housing system).

Where possible the default values in the model were replaced with data collected during the study (weaning and finished pig weight; growth rate and FCR values for weaning to 30 kg and 30 to 100 kg; sow and creep feed intake), with other input costs taken from Beaton (2006). As AGEWEAN only ran for four parities, and the removal of sows from trial was dictated by experimental as opposed to commercial conditions, it was not possible to derive a commercially meaningful figure for pigs produced per sow per year for the trial animals. Therefore standard UK litter performance under 4-week weaning was used (BPEX Pig Yearbook, 2006) and scaled to 6 and 8 weeks according to effects observed on the numbers of pigs produced per sow day on trial under the AGEWEAN study (reduction in number of piglets weaned/sow/year by 1.8 and 4.0 respectively).

The impact of future changes (+/-10%) in either feed price or energy (power) costs were also explored. Although all known costs were accounted for, values of the cost of pigmeat production under different weaning ages presented below should be interpreted with care as they are at best only estimates of the true values.

Table 14 - Overview of three different housing systems compared under 3 different weaning ages

System	**Indoor**			**Indoor straw-based**			**Outdoor**		
Weaning age	**4**	**6**	**8**	**4**	**6**	**8**	**4**	**6**	**8**
Pregnant sow	Kennel‡, SS	Kennel‡, SS	Kennel‡, SS	Yard ESF DS	Yard ESF DS	Yard ESF DS	Paddock & hut (¶)	Paddock & hut	Paddock & hut
Farrowing sow	Crate FS	Opening crate FS	Opening crate FS	Opening crate FS	Opening crate FS	Opening crate FS	Paddock & hut	Paddock & hut	Paddock & hut
Weaners I (8-20 kg)	Flat deck FS	Flat deck FS	-	Kennel SS	Kennel SS	-	Outdoor kennel & run	Outdoor kennel & run	-
Weaners II (20-35 kg)	Flat deck FS	Flat deck FS	Flat deck FS	Kennel SS	Kennel SS	Kennel SS	Outdoor kennel & run	Outdoor kennel & run	Outdoor kennel & run
Growers (35-60 kg)	Enclosed FS	Enclosed FS	Enclosed FS	Kennel SS	Kennel SS	Kennel SS	Yards DS	Yards DS	Yards DS
Finishers (60-100 kg)	Enclosed FS	Enclosed FS	Enclosed FS	Kennel SS	Kennel SS	Kennel SS	Yards DS	Yards DS	Yards DS

FS Fully-slatted floor; SS Shallow cover of straw spread on the floor; DS Deep cover of straw, ‡ Individual Feeder

Results

The cost of production for weaners (£/piglet weaned) and overall rearing (£/kg carcass) for all 3 weaning ages and 3 housing systems are given in Table 15. This shows that weaning age had a major impact on the cost of producing a weaner pig, increasing from approximately £27 for a 4-week weaner to over £38 for an 8-week weaner in indoor systems. A similar spread was observed for straw-based and outdoor systems. It should be remembered that these values mask the differences in the size of the weaner pig produced under the three different weaning ages.

Values in Table 15 show that the cost of pigmeat production was lowest in the indoor system, with a cost of £1.05 per kg/carcass. This is comparable to the recent BPEX estimate of the 2005 cost of pigmeat production in Great Britain of £1.04/kg (BPEX, 2006). Housing pigs in an indoor straw-based system resulted in a modest increase in production costs (approximately £0.02 per kg), whilst outdoor housing resulted in a major increase in the cost of production (approximately £0.05 per kg carcass), as a result of their poorer feed efficiency. The lowest cost of production per kg pigmeat in each housing system was achieved where piglets were weaned at 4 weeks of age. Increasing weaning age from 4 to 6 weeks resulted in a modest increase in the cost of pigmeat production, by approximately 3 p/kg carcass. Further increase in weaning age from 6 to 8 weeks had relatively no effect on cost of pigmeat production. It appears that the increased cost of producing a weaner pig at 8 weeks of age compared to 6 weeks of age (associated with relatively higher costs of sow feed, farrowing accommodation, labour input etc.) is offset by the savings in rearing costs associated with a much larger pig entering the rearing system (17kg versus 12 kg). An example of the cost breakdown for one system is shown in Table 16.

Table 15 - Estimates of sow output and cost of pigmeat production for three different housing systems compared under 4, 6 and 8 week weaning

System	**Indoor**			**Indoor straw-based**			**Outdoor**		
Weaning age	4 weeks	6 weeks	8 weeks	4 weeks	6 weeks	8 weeks	4 weeks	6 weeks	8 weeks
Sow costs (£/sow)	587.97	636.26	697.46	613.40	668.80	721.60	513.00	552.32	588.86
Pigs weaned /sow/yr‡	22.1	20.28	18.09	22.1	20.28	18.09	21.20	19.38	17.19
Cost/weaner (£)	26.60	31.37	38.56	27.76	32.98	39.89	24.20	28.50	34.26
COP (£/kg carc wt)	1.05	1.08	1.08	1.07	1.10	1.11	1.12	1.15	1.15

‡ Base level for 4-week weaning taken as number of piglets weaned per sow per year for indoor and outdoor herds from MLC Pig Yearbook (MLC, 2006), scaled to 6 and 8 weeks according to AGEWEAN data. COP = Cost of production

Table 16 – Breakdown of cost of pigmeat production for 4, 6 or 8 week weaning in an indoor, straw-based system

Parameter	4 weeks		6 weeks		8 weeks	
Variable costs	£/pig	£/kg cw	£/pig	£/kg cw	£/pig	£/kg cw
Feed	40.60	0.54	38.78	0.52	33.58	0.45
Vet. and Med.	0.93	0.01	0.79	0.01	0.67	0.01
Bedding	1.73	0.02	1.65	0.02	1.61	0.02
Total variable costs	43.26	0.58	41.21	0.55	35.85	0.48
Fixed costs						
Housing	3.56	0.05	3.30	0.04	3.11	0.04
Labour	4.27	0.06	3.76	0.05	3.05	0.04
Energy	0.20	0.00	0.10	0.00	0.00	0.00
Water	0.48	0.01	0.46	0.01	0.44	0.01
Slurry/muck storage and disposal	0.94	0.01	0.91	0.01	0.90	0.01
Total fixed costs	9.45	0.13	8.53	0.11	7.50	0.10
Total rearing costs	52.71	0.70	49.74	0.66	43.35	0.58
Weaner value	27.76	0.37	32.98	0.44	39.89	0.53
Total costs	80.47	1.07	82.72	1.10	83.24	1.11

The impact of future changes in either feed prices or energy (power) costs were explored using scenarios methodology as shown in Tables 17 and 18 respectively. Both a 10 % increase and decrease in feed cost were explored. A 10% increase in feed costs increased the cost of pigmeat production by approximately 6 p/kg carcass and affected all three housing systems relatively equally. The impact of a 10% increase in the cost of power had a relatively minor effect on the cost of production for indoor and straw-based housing systems and no detectable effect on cost of production for outdoor housing.

Table 17 – Cost of pigmeat production affected by a 10% change in feed cost

	Cost of production (£/kg carcass)								
	4 weeks			6 weeks			8 weeks		
	-10 %	0	+10 %	-10 %	0	+10 %	-10 %	0	+10 %
Indoor (slats)	0.99	1.05	1.11	1.02	1.08	1.14	1.02	1.08	1.14
Indoor (straw)	1.01	1.07	1.13	1.04	1.10	1.17	1.05	1.11	1.17
Outdoor	1.07	1.12	1.17	1.09	1.15	1.20	1.09	1.15	1.20

Table 18 – Cost of pigmeat production affected by a 10% change in energy (power) cost

	Cost of production (£/kg carcass)								
	4 weeks			6 weeks			8 weeks		
	-10 %	0	+10 %	-10 %	0	+10 %	-10 %	0	+10 %
Indoor (slats)	1.05	1.05	1.05	1.08	1.08	1.08	1.08	1.08	1.08
Indoor (straw)	1.07	1.07	1.07	1.10	1.10	1.10	1.11	1.11	1.11
Outdoor	1.12	1.12	1.12	1.15	1.15	1.15	1.15	1.15	1.15

Since the data on outdoor production included some animals which spent the entire rearing to finishing period outdoors, estimates of the cost of production for outdoor systems were also made using growth rate and FCR data from the indoor systems i.e. the spreadsheet models were run using indoor weaner/finisher feed efficiency values for the outdoor housing scenario. The results in Table 19 show that had these higher levels of pig performance been achieved, there would have been a considerable reduction in the cost of production outdoors to bring it in line with indoor and indoor straw-based housing systems.

Table 19 – Cost of pigmeat production in different systems using either AGEWEAN outdoor or indoor weaner/finisher performance data for the outdoor system

	Cost of production (£/kg carcass)		
	4 weeks	6 weeks	8 weeks
Indoor	1.05	1.08	1.08
Indoor straw-based	1.07	1.10	1.11
Outdoor (outdoor rearing data)	1.12	1.15	1.15
Outdoor (indoor rearing data)	1.04	1.08	1.06

The data generated in the systems study will also be used as input to a life cycle assessment of the different weaning ages in a collaborative investigation following modifications to the LCA pigmeat model of Cranfield University.

OVERALL CONCLUSIONS

There were significant benefits from later weaning in terms of piglet performance during the immediate postweaning period. These were reflected in later weaned piglets having significantly better feed intakes and daily liveweight gains, and a more favourable gut microflora. Pigs weaned at later ages were also significantly less likely to be removed from trial or die during the weaning to slaughter period. However, when performance was considered over the full period from birth to slaughter, no overall benefits of later weaning were seen.

In terms of sow productivity, there was a significant production penalty to be paid by later weaning. Sows weaned at 8 weeks of age produced the equivalent of 4 fewer piglets per year than sows weaned at 4 weeks of age.

Modelling of the overall system economics to take account of pig performance and resource requirements in the form of both fixed and variable costs, indicated a lower production cost for the 4-week weaning system in comparison with the 6- or 8-week weaning system (by approximately 3p/kg carcass weight in 2007, or 2.8%).

Both economic and environmental evaluations indicated best efficiency for the 4 week system. Pigs in the 8-week weaning system received over 10g more phosphorus and over 500g more nitrogen in feed inputs to reach slaughter weight when compared to the 4-week weaning system.

Under current UK conditions, and with appropriate nutrition and management, later weaning of piglets at 6 or 8 weeks of age therefore appears to offer no significant benefits for health or performance of the progeny which outweigh the reduction in sow output when compared to the current industry norm of 4 week weaning.

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KNOWLEDGE DISSEMINATION

The project progress was presented and discussed at Stakeholder meetings with industry representation from BPEX on 4/2/04, 8/10/04, 15/7/05, 13/2/06, 18/12/06 and 19/12/07.

A. Project Reports

1. AGEWEAN: Sustainable systems for pig weaner management. Parallel experiment to assess environmental impact of weaning age. Final Report. ADAS Consulting Ltd. April 2006. 35 pp.
2. The effect of weaning age on pig health, performance, economics and environmental impact. The "AGEWEAN" project, Final Report. University of Newcastle, August 2007. 91pp.

B. Conference presentations

1. ***Pig Veterinary Society (16/11/2005)***
   Never too old to wean?
2. ***BSAS Annual Meeting, York (27-29/03/06)***
   AGEWEAN - The effect of weaning age on the performance of sows and their progeny in the first parity.
3. ***International Pig Veterinary Society Congress, Copenhagen (16-19/7/2006)***
   AGEWEAN – The effect of weaning age on growing pig performance in the absence of antibiotic growth promoters.
4. ***57th Annual Meeting of the European Association for Animal Production, Antalya (17-20/9/2006)***
   a. The environmental impact of increasing weaning age.
   b. The effect of weaning age on health and lifetime performance of growing pigs.
5. ***BSAS Annual Meeting, Southport (2-4/04/07)***
   AGEWEAN – The effect of weaning age on sow performance over 4 parities.
6. ***Society of Feed Technologist & Pig Veterinary Society joint conference, Coventry (15-16/11/2007)***
   AGEWEAN: weaning age sorted
7. ***BSAS Annual Meeting, Scarborough (2008)***
   Agewean – The effect of weaning age on growing pig health and performance in the absence of antibiotic growth promoters.

C. Other presentations

1. **BPEX organised industry meeting (17/11/2005)**
   When to wean? A farm system analysis. by Sandra Edwards
2. ***Cambridge Pig Discussion Group (Feb 2006)***
   Outline of the Agewean project by Miriam Drewett
3. ***Essex Pig Discussion Group (April 2006)***
   Presentation on the Agewean project by Lisa Taylor
4. ***Pig & Poultry Fair, Stoneleigh (April 2006)***
   Poster on the Agewean project
5. ***Pig Health and Welfare Council, London (06/12/06)***
   A presentation on the Agewean project and interim results by Sandra Edwards

D. Industry publications

1. "Agewean project results". BPEX Tech Talk (December 2006)
2. "Agewean" BPEX Annual Technical Report 2006 p32-33.
3. "Agewean" BPEX Annual Technical Report 2007, in press.

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

Edge HL, Brade M, Hillman K, Morgan CA, Stewart A, Strachan WD, Taylor L, Theobald CM, Edwards SA. 2006. Never too old to wean? The Pig Journal, 57: 150-157.

Edge HL, Breuer K, Hillman K, Morgan CA, Stewart A, Strachan WD, Taylor L, Theobald CM, Edwards SA. 2006. Proceedings of the British Society of Animal Science 2006, p25.

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Edge HL, Breuer K, Hillman K, Morgan CA, Stewart A, Strachan WD, Taylor L, Theobald CM, Edwards SA. 2006. The effect of weaning age on health and lifetime performance of growing pigs. Proc 57th Annual Meeting EAAP, 2006, p172.

Breuer K, Docking C, Agostini F, Smith K. 2006. The environmental impact of increasing weaning age. Proc 57th Annual Meeting EAAP, 2006, p229.

Edge HL, Breuer K, Hillman K, Morgan CA, Stewart A, Strachan WD, Taylor L, Theobald CM, Edwards SA. 2007. AGEWEAN – The effect of weaning age on sow performance over 4 parities. Proceedings of the British Society of Animal Science 2007, p85.

Edwards SA, Edge HL, Breuer K, Hillman K, Morgan CA, Stewart A, Strachan WD, Taylor L, Theobald CM. 2007. AGEWEAN: weaning age sorted. Proceedings of the Society of Feed Technologists, November 2007.

Edge HL, Breuer K, Hillman K, Morgan CA, Stewart A, Strachan WD, Taylor L, Theobald CM, Edwards SA. 2008. Agewean – The effect of weaning age on growing pig health and performance in the absence of antibiotic growth promoters. Proceedings of the British Society of Animal Science 2008, p10.

A series of papers for submission to refereed journals are currently in preparations:

1. Consequences of different weaning ages for the lifetime health and performance of growing pigs.
2. Consequences of different weaning ages for the lifetime health and performance of sows.
3. Consequences of different weaning ages for the environmental impact of pigmeat production.
4. Consequences of different weaning ages for the cost of pigmeat production.