**Agricultural Research Institute of Northern Ireland**
*Large Park, Hillsborough, Co. Down, BT26 6DR*

# Advances in Pig Research

## 24th June 2004

**Proceedings of a Seminar held at The Agricultural Research Institute of Northern Ireland**

**Occasional Publication No. 33**

Department of Agriculture and Rural Development
www.dardni.gov.uk

Large Park, Hillsborough, Co Down BT26 6DR
Tel: 028 9268 2484 Fax: 028 9268 9594
E-mail: arini@dardni.gov.uk Website: www.arini.ac.uk

# Today's research is tomorrow's industry

The main objective of the research programme at Hillsborough is to enhance the competitiveness of the agricultural and food industries within Northern Ireland. This research also takes account of the needs of the community for high quality food, conservation of the environment and welfare of animals.

## PIG TEAM

**Back Row** (Left to Right) Declan Armstrong, Peter Ffrench-Mullan,
Roy McCagherty, Dennis Watt, David Lyttle
**Front Row** (Left to Right) Elizabeth Magowan, Lavinia Wright,
Elizabeth McCann, Norman Morgan and Niamh O'Connell

## SPEAKERS

Elizabeth Magowan, Elizabeth McCann, Niamh O'Connell and Gordon Allan

# TABLE OF CONTENTS

# INTRODUCTION

This is the fourth in a series of seminars specifically designed to highlight current research on pig production and welfare at the Agricultural Research Institute of Northern Ireland (ARINI). From the outset, the objective of these seminars has been to ensure that results of research undertaken at the Institute are disseminated as widely as possible to the agri-food industry in Northern Ireland. In particular, the target audience for the seminars are those directly involved in provision of specialist technical support to pig producers. The seminars enable a more in-depth insight into the current research programme at ARINI, as well as providing an excellent opportunity for those closely involved in the industry to comment on our current research programme and to suggest priorities for future research.

The pig production and welfare programme at the Institute is primarily funded by the Department of Agriculture and Rural Development (DARD). However we also acknowledge the very significant practical and financial support from a number of groups, particularly the Pig Production Development Committee. The long standing partnership between ARINI, DARD and John Thompson and Sons Ltd and Devenish Nutrition Ltd also enables very effective interaction between ARINI/DARD scientists and leading industry specialists, in addition to providing valuable financial support.

There have been major staff changes in the Institute's pig production and welfare research team in the two years since the last seminar. The new research team are now well established, extremely enthusiastic and very committed to the pig industry in Northern Ireland. I am confident they will continue the sterling work of their predecessors.

The theme of the current seminar is: **"Advances in Pig Research"**

The papers being presented in the seminar and published here in full address a wide spectrum of current issues, ranging from practical issues such as predicting backfat depth in live pigs, through effects of feeder type on feed intake and performance of weaned pigs, welfare of sows in dynamic groups and designing pig diets to reduce phosphorus loss to the environment. We are also pleased to welcome Dr Gordon Allan from Veterinary Science Division, who has been at the forefront of research on the latest pig disease, PMWS, to present a paper on the findings of his work on this important new disease.

It is our objective that today's seminar will provide an opportunity to discuss results of the latest research work undertaken at the Institute and that the information presented will assist pig producers, and the entire industry in Northern Ireland, to move forward into a more profitable future.

**Sinclair Mayne**

# THE EFFECT OF FEEDER TYPE AND CHANGE ON PIG PERFORMANCE AND BEHAVIOUR

**M. Elizabeth E. McCann, Elizabeth Magowan and Niamh E. O Connell**

## Introduction

Reduction in feed intake at weaning has been reported to result in a post-weaning “growth check”. This reduction in feed intake may be caused by a number of factors including the change in both diet and environment. A recent study at the Agricultural Research Institute of Northern Ireland (ARINI) indicated that a similar “growth check” occurs when pigs are transferred to finishing accommodation at 10 weeks of age. It was observed that pigs gaining 666 g/d in the period between 7 and 10 weeks gained only 521 g/d in the week following transfer to finishing accommodation.

Factors similar to those involved at weaning may contribute to this “growth check” at transfer. For example, the stress of being transported and mixed and also the fact that feed is offered in unfamiliar feeders. Mixing and transportation have been reported to be a common cause of stress in pigs. For example, Ekkel *et al.,* (1995) compared the performance and behaviour of pigs housed in specific-stress free (SSF) housing with those under commercial conditions. The SSF system was based on birth-to-finish accommodation whereas the commercial system involved movement and mixing of pigs at weaning and at 61 days of age. Feed intake and average daily gain were significantly higher for pigs housed under the SSF system than those housed under the commercial system. Furthermore, Bilkei *et al.* (1997) compared the performance and health status of pigs housed in the same accommodation from weaning to finish with those moved three times during this period. It was reported that pigs that were not moved had better feed conversion, lower mortality and fewer infectious and stress related diseases than their moved counterparts. These findings are similar to those of Mardarowicz, (1985) who investigated the effect of housing pigs in three different production systems; birth-to-finishing accommodation, weaning-to-finishing accommodation and weaning-to-growing-to-finishing accommodation. It was concluded that moving pigs was a stressful process which resulted in reduced liveweight gain, less efficient feed conversion and increased incidences of pneumonia compared with pigs that were not moved.

Despite the evidence to indicate that moving pigs reduces production performance, there are few units where pigs could be housed in the same accommodation from birth to finish. Therefore, it is the aim of the producer to reduce stress at moving in order to reduce the subsequent growth check. One possible means of achieving this is to minimise the extent of change when pigs are moved from one pen to another i.e. to house pigs in the same groups and to offer feed in the same type of feeder as in post-weaning accommodation.

Several studies have examined the effect of feeder design on pig performance at both the post-weaning stage and the finishing stage. Walker, (1990) investigated the effect of single and multi space feeders on growing pigs and concluded that although there was no significant difference in pig performance as a result of feeder design, feeders which provided water ("wet and dry") resulted in higher growth rates and feed intakes than "dry" feeders. Previous research by Patterson and Walker, (1989) indicated "wet and dry" multi space feeders did not improve performance when compared with "dry" multi space feeders and it was therefore recommended that the "wet and dry" single space feeder was optimum for growing and finishing pigs. O'Connell *et al.*, (2002) compared five different feeder types for post-weaned pigs and reported that the "dry" multi space feeder was optimum for weaned pigs. Therefore, the practice at ARINI is to offer post-weaned pigs feed in "dry" multi space feeders up to 10 weeks of age and at transfer to the finishing accommodation to offer feed in "wet and dry" single space feeders. It was postulated that this change in feeder design could further exacerbate the "growth check" at transfer and it was suggested that feed should be offered in the same type of feeder from weaning to finish.

The aim of this study was therefore to compare the performance and behaviour of pigs offered feed in the same type of feeder from weaning to finish with those offered feed from two different types of feeder.

## Materials and Methods

### Experimental design and animals

A total of 640 3/4 Landrace x 1/4 Large White pigs were weaned at 4 weeks of age and balanced for weight and gender into groups of 20 which were randomly allocated to one of four treatments over 8 replicates (Table 1).

Pigs on treatment 1 and 2 were offered feed from the same type of feeder from weaning to finish whereas those pigs on treatments 3 and 4 were offered feed from two different feeder types during the period from weaning to finish. This change occurred at 10 weeks of age when pigs moved from combined stage 1/stage 2 accommodation to finishing accommodation.

**Table 1** Experimental treatments

| | Age | | |
|---|---|---|---|
| **Treatment** | **4 - 10 weeks** | **10 weeks - Finish*** | **Abbreviation** |
| **1** | "Wet and dry" single space feeder | "Wet and dry" single space feeder | S-S |
| **2** | "Dry" multi space feeder | "Dry" multi space feeder | M-M |
| **3** | "Wet and dry" single space feeder | "Dry" multi space feeder | S-M |
| **4** | "Dry" multi space feeder | "Wet and dry" single space feeder | M-S |

* Finish : 21 weeks + 5 days

The "dry" multi space feeder (Etra Feeders, Northern Ireland) was of traditional design with the feed hopper connected directly to the trough with an adjustable aperture to regulate feed flow. The "wet and dry" single space feeder (Verba, Verbakel™, The Netherlands) contained the trough and feed hopper within side partitions. Feed was dispensed from the hopper by the pig pushing a panel at the back of the feeder. One nipple drinker was located within the trough beside the panel. The dimensions of the trough size varied according to the age of the pig. Table 2 describes the trough dimensions for the "wet and dry" single space and "dry" multi space feeders in stage 1/stage 2 accommodation and the finishing accommodation. The dimensions given for the multi space feeder refer to only one compartment within the feeder.

**Table 2** The dimensions of the trough of the various feeders

| | | Dimensions (cm) | | |
|---|---|---|---|---|
| | | **Width** | **Length** | **Depth** |
| Single space | Stage 1/Stage 2 | 22.5 | 20.0 | 10.0 |
| | Finishing | 34.5 | 42.5 | 17.5 |
| Multi space | Stage 1/Stage 2 | 20.0 | 16.4 | 12.5 |
| | Finishing | 29.5 | 20.0 | 14.0 |

After weaning, pigs were housed in combined stage 1/stage 2 accommodation (0.38m$^2$/pig) with plastic slatted floors. Temperature was 28ºC on the first day of treatment which was reduced by 0.5ºC/day to 18ºC where it remained for the rest of the treatment period. The pigs were exposed to natural lighting through windows and artificial lighting (6250 lux) during feeding. Pelleted diets were offered *ad libitum* throughout the trial period. Commercial diets were offered between 4 and 8 weeks of age after which pelleted diets formulated at ARINI were offered to finish.

### Measurements

Production performance

Pigs were individually weighed and growth rates were established at 4, 7, 10, 11, 12, 15 and 18 weeks of age and finish (21 weeks + 5 days). Feed intakes were also taken at these stages. Average daily gain (ADG g/d), average daily feed intake (ADFI g/d) and feed conversion ratios (FCR) were subsequently calculated.

Behavioural measures

The behaviour of pigs on each treatment was videotaped continuously during two 24 hour periods in the first and fourth week of the finishing period (10 - 11 weeks of age and 13 - 14 weeks of age respectively). Video tapes were analysed to determine the number of pigs at the feeder at 20 minute intervals. The frequency of fights, headthrusts and displacements from the feeder were also recorded for 30 seconds at each sampling interval.

## Results

### The effect of feeder change on production performance and behaviour

Table 3 presents the ADG, ADFI and FCR of pigs at various stages of growth when offered feed from the same feeder throughout the weaning to finish period (not changed) compared with those offered feed from two different feeder types (changed). Significantly higher ADG's were attained during the periods 11 - finish, 12 - finish, 15 - finish and 18 - finish when the type of feeder was changed at 10 weeks of age (all P<0.05). However, there was no significant difference in ADG from weaning to finish due to a change in feeder type.

Apparent feed intake was higher (P<0.01) for pigs offered feed from the same feeder during 10 - 11 weeks of age. However, this trend was reversed during the period 12 - finish (P<0.05).

When feeder type was changed at 10 weeks of age, FCR improved for the periods 11 - finish and 15 - finish (2% and 3% respectively).

The number of pigs at the feeder during the periods between weeks 10 and 11 and weeks 13 and 14 was significantly greater (P<0.05) when the feeder type changed (Table 4). However a change in feeder had no significant effect on the aggressive behaviour of the pigs (Table 4).

**Table 3** The effect of feeder change on average daily gain (ADG g/d), average daily feed intake (ADFI g/d) and feed conversion ratio (FCR) at various stages of growth

| | Age (wks) | Treatment 1 & 2 Not changed | Treatment 3 & 4 Changed | SEM | P |
|---|---|---|---|---|---|
| **ADG (g/d)** | 4 - 7 | 306 | 319 | 6.0 | NS |
| | 7 - 10 | 632 | 626 | 10.7 | NS |
| | 10 - 11 | 556 | 498 | 27.8 | NS |
| | 11 - 12 | 748 | 757 | 11.3 | NS |
| | 10 - finish | 811 | 829 | 6.9 | NS |
| | 11 - finish | 834 | 865 | 7.5 | <0.05 |
| | 12 - finish | 845 | 880 | 7.3 | <0.05 |
| | 15 - finish | 867 | 906 | 7.0 | <0.05 |
| | 18 - finish | 880 | 919 | 8.7 | <0.05 |
| | Wean - finish | 700 | 715 | 5.5 | NS |
| **ADFI (g/d)** | 4 - 7 | 392 | 406 | 6.0 | NS |
| | 7 - 10 | 1048 | 1032 | 14.9 | NS |
| | 10 - 11 | 1333 | 1261 | 14.2 | <0.01 |
| | 11 - 12 | 1586 | 1569 | 14.3 | NS |
| | 10 - finish | 2061 | 2093 | 17.7 | NS |
| | 11 - finish | 2141 | 2190 | 24.4 | NS |
| | 12 - finish | 2192 | 2252 | 15.0 | <0.05 |
| | 15 - finish | 2355 | 2401 | 20.8 | NS |
| | 18 - finish | 2505 | 2548 | 24.6 | NS |
| | wean - finish | 1642 | 1626 | 25.1 | NS |
| **FCR** | 4 - 7 | 1.29 | 1.27 | 0.020 | NS |
| | 7 - 10 | 1.66 | 1.66 | 0.021 | NS |
| | 10 - 11 | 2.43 | 2.59 | 0.135 | NS |
| | 11 - 12 | 2.13 | 2.09 | 0.027 | NS |
| | 10 - finish | 2.55 | 2.53 | 0.010 | NS |
| | 11 - finish | 2.58 | 2.54 | 0.009 | <0.05 |
| | 12 - finish | 2.60 | 2.56 | 0.013 | NS |
| | 15 - finish | 2.72 | 2.65 | 0.016 | <0.05 |
| | 18 - finish | 2.85 | 2.78 | 0.030 | NS |
| | Wean - finish | 2.35 | 2.28 | 0.040 | NS |

**Table 4** The effect of feeder change on aggressive behaviour (freq/30 sec) and number of pigs at the feeder (average of weeks 10 - 11 and 13 - 14)

| | **Treatment 1 & 2 Not changed** | **Treatment 3 & 4 Changed** | **SEM** | **P** |
|---|---|---|---|---|
| Headthrusts | 0.03 | 0.03 | 0.010 | NS |
| Fights | 0.01 | 0.01 | 0.003 | NS |
| Displacements from feeder | 0.08 | 0.08 | 0.010 | NS |
| Total aggression | 0.12 | 0.11 | 0.018 | NS |
| Number of pigs at the feeder | 0.49 | 0.56 | 0.024 | <0.05 |

**The effect of feeder type and change on production performance and behaviour**

Table 5 presents the ADG, ADFI and FCR of pigs on the different treatments at various stages of growth. When pigs were offered feed on treatment “dry” multi space feeder to “wet and dry” single space feeder a higher ADG was attained between weaning and finish (P<0.05) especially during the period 10 - finish (P<0.05), 11 - finish (P<0.01), 12 - finish (P<0.01) and 15 - finish (P<0.05). Although not significant this trend was also apparent during 18 - finish. Feeder type and change had no significant effect on the ADG of pigs in weeks 10 - 11.

Pigs consumed significantly less (P<0.05) feed during weeks 10 and 11 when the feeder type changed. However this trend was not continued after 11 weeks of age and did not affect the average daily feed intake from wean (4 weeks) to finish.

Treatment had a significant (P<0.05) effect on FCR during weeks 4 to 7 i.e. stage 1 with pigs offered feed from “dry” multi space feeders having lower FCR’s than those offered feed from “wet and dry” single space feeders. Although there was no significant effect of treatment on FCR at other stages of growth, it was apparent that the FCR of those pigs which were exposed to a change in feeder type (“wet and dry” single space feeder to “dry” multi space feeder and “dry” multi space feeder to “wet and dry” single space feeder) was lower than that of pigs which were not. This trend was also apparent in the overall FCR from wean to finish.

There were no interactive effects between treatment and week on total aggression or on the number of pigs at the feeder. A greater level of aggressive behaviour (P<0.001), especially in terms of displacement from the feeder (P<0.001) and headthrusts at the feeder (P<0.05), was observed when pigs were offered feed from single space feeders in the finishing period (Table 6).

**Table 5** The effect of treatment on average daily gain (ADG g/d), average daily feed intake (ADFI g/d) and feed conversion ratio (FCR) at various stages of growth

| | **Age (weeks)** | **Treatment** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **S-S** | **M-M** | **S-M** | **M-S** | **SEM** | **P** |
| **ADG (g/d)** | 4 - 7 | 309 | 303 | 314 | 324 | 8.6 | NS |
| | 7 - 10 | 637 | 627 | 621 | 632 | 11.2 | NS |
| | 10 - 11 | 574 | 538 | 513 | 482 | 28.0 | NS |
| | 11 - 12 | 725 | 772 | 723 | 791 | 29.1 | NS |
| | 10 - finish | 809 | 814 | 808 | 850 | 9.1 | <0.05 |
| | 11 - finish | 831 | 838 | 844 | 886 | 8.9 | <0.01 |
| | 12 - finish | 844 | 846 | 859 | 900 | 9.1 | <0.01 |
| | 15 - finish | 864 | 870 | 890 | 922 | 10.1 | <0.01 |
| | 18 - finish | 871 | 889 | 902 | 925 | 17.9 | NS |
| | wean - finish | 702 | 699 | 701 | 730 | 6.7 | <0.05 |
| **ADFI (g/d)** | 4 - 7 | 402 | 382 | 418 | 395 | 7.7 | NS |
| | 7 - 10 | 1066 | 1030 | 1044 | 1020 | 17.1 | NS |
| | 10 - 11 | 1359 | 1306 | 1261 | 1260 | 25.7 | <0.05 |
| | 11 - 12 | 1593 | 1579 | 1512 | 1627 | 33.4 | NS |
| | 10 - finish | 2037 | 2085 | 2072 | 2115 | 26.3 | NS |
| | 11 - finish | 2105 | 2177 | 2166 | 2214 | 29.5 | NS |
| | 12 - finish | 2162 | 2222 | 2222 | 2282 | 31.3 | NS |
| | 15 - finish | 2305 | 2405 | 2392 | 2411 | 30.2 | NS |
| | 18 - finish | 2445 | 2566 | 2546 | 2549 | 35.2 | NS |
| | wean - finish | 1632 | 1651 | 1607 | 1645 | 26.5 | NS |

**Table 5 (contd)**

| | Age (weeks) | Treatment | | | | | |
|---|---|---|---|---|---|---|---|
| | | S-S | M-M | S-M | M-S | SEM | P |
| **FCR** | 4 - 7 | 1.31 | 1.27 | 1.33 | 1.21 | 0.028 | <0.05 |
| | 7 - 10 | 1.68 | 1.65 | 1.69 | 1.62 | 0.025 | NS |
| | 10 - 11 | 2.42 | 2.45 | 2.50 | 2.69 | 0.121 | NS |
| | 11 - 12 | 2.23 | 2.06 | 2.14 | 2.07 | 0.069 | NS |
| | 10 - finish | 2.53 | 2.57 | 2.54 | 2.49 | 0.033 | NS |
| | 11 - finish | 2.54 | 2.59 | 2.54 | 2.48 | 0.033 | NS |
| | 12 - finish | 2.57 | 2.63 | 2.59 | 2.54 | 0.041 | NS |
| | 15 - finish | 2.68 | 2.77 | 2.69 | 2.65 | 0.045 | NS |
| | 18 - finish | 2.83 | 2.89 | 2.84 | 2.73 | 0.077 | NS |
| | wean - finish | 2.34 | 2.37 | 2.29 | 2.26 | 0.040 | NS |

S - S : “wet and dry” single space to “wet and dry” single space; M - M : “dry” multi space to “dry” multi space; S - M: “wet and dry” single space to “dry” multi space; M - S : “dry” multi space to “wet and dry” single space

**Table 6** Effect of treatment on aggressive behaviour and number of pigs at the feeder (average of weeks 10 - 11 and 13 - 14)

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | S-S | M-M | S-M | M-S | SEM | P |
| Headthrusts | 0.05 | 0.01 | 0.02 | 0.04 | 0.010 | <0.05 |
| Fights | 0.01 | 0.01 | 0.01 | 0.01 | 0.003 | NS |
| Displacements from feeder | 0.13 | 0.03 | 0.03 | 0.12 | 0.010 | <0.001 |
| Total aggression | 0.20 | 0.05 | 0.06 | 0.17 | 0.018 | <0.001 |
| Number of pigs at the feeder | 0.53 | 0.46 | 0.51 | 0.60 | 0.024 | <0.01 |

S - S : “wet and dry” single space to “wet and dry” single space; M - M : “dry” multi space to “dry” multi space; S - M: “wet and dry” single space to “dry” multi space; M - S : “dry” multi space to “wet and dry” single space

## Effect of feeder type on production performance

Table 7 presents ADG, ADFI and FCR values at various stages of growth for pigs that were offered feed from either a "wet and dry" single space feeder or a "dry" multi space feeder in either stage1/stage 2 or the finishing stage. Pigs offered feed in stage 1 (4 - 7 weeks) from a single space feeder had significantly higher ADFI (P<0.05) and FCR (P<0.01) than pigs offered feed from a multi space feeder. However, no difference in ADG was observed. Although this trend did not continue in stage 2 (weeks 7 - 10) it was apparent when data from stage 1/stage 2 were combined (weeks 4 - 10). The type of feeder in the finishing stage had no effect on ADG, ADFI or FCR.

**Table 7** Average daily gain (ADG g/d), average daily feed intake (ADFI g/d) and feed conversion ratio (FCR) at various stages of growth for pigs offered feed from either the "wet and dry" single space feeders or "dry" multi space feeders.

| | | **Feeder type** | | | |
|---|---|---|---|---|---|
| | **Age (weeks)** | **"Wet & dry" single space** | **"Dry" multi space** | **SEM** | **P** |
| ADG (g/d) | 4 - 7 | 312 | 314 | 7.0 | NS |
| | 7 - 10 | 629 | 629 | 5.8 | NS |
| | 4 - 10 | 475 | 475 | 4.5 | NS |
| ADFI (g/d) | 4 - 7 | 410 | 388 | 6.0 | <0.05 |
| | 7 - 10 | 1055 | 1025 | 11.9 | NS |
| | 4 - 10 | 742 | 716 | 7.7 | <0.05 |
| FCR | 4 - 7 | 1.32 | 1.24 | 0.012 | <0.01 |
| | 7 - 10 | 1.68 | 1.64 | 0.015 | NS |
| | 4 - 10 | 1.57 | 1.51 | 0.013 | <0.05 |
| ADG (g/d) | 10 - finish | 829 | 811 | 6.5 | NS |
| ADFI (g/d) | 10 - finish | 2076 | 2078 | 16.1 | NS |
| FCR | 10 - finish | 2.50 | 2.57 | 0.019 | NS |

## Discussion

### The effect of feeder change

The hypothesis at the beginning of this study was that offering pigs feed from the same feeder type throughout the weaning to finish period would reduce the "growth check" at transfer and improve production performance. The results of the study proved this hypothesis incorrect as the average daily gains of pigs offered feed from a different feeder type (changed) at 10 weeks of age were higher ($P<0.05$) from 11 weeks to finish (865 vs. 834 g/d) than those pigs whose feeder type did not change over the entire weaning to finish period. This was a result of numerically higher intakes and slightly more efficient conversion of feed to gain throughout this period. The greater number of pigs at the feeder for those on the "changed" treatment may indicate that the change in feeder at the start of the finishing period stimulated pigs to explore and use the feeder.

It is interesting to note that during weeks 10-11, daily feed intake was higher for those pigs on the "not changed" treatment. This resulted in a numerically higher average daily gain (556 vs. 498 g/d). However, the large standard errors would suggest that there was wide variation within the pens which masked any effect of treatment between the pens. Further analysis of the data is required to investigate the effect of feeder type on the variability of performance.

### The effect of feeder type

Pigs offered feed from "dry" multi space feeders up to 10 weeks of age and then changed over to "wet and dry" single space feeders on transfer to finishing accommodation gave the best overall performance in terms of improving average daily gain. The better performance of post-weaned pigs offered feed from "dry" multi-space feeders is in keeping with previous research on feeder types. O'Connell *et al.*, (2002) recommended the use of "dry" multi-space feeders during the post-weaning period (4-10 weeks) and reported higher gains and feed intakes and less aggression with this type of feeder. It was concluded that the presence of greater numbers of feeding spaces in the multi-space feeder reduced competition and stimulated pigs to feed together as they did prior to weaning (Fraser *et al.*, 1998; Petherick and Blackshaw, 1987). In contrast to O'Connell *et al.*, (2002), feed conversion was more efficient for pigs offered feed from the "dry" multi-space feeders as opposed to the "wet and dry" single space feeders (Table 7) (1.51 vs. 1.57). It is possible that the "wet and dry" feeders resulted in more feed wastage through the accumulation of wet unpalatable feed and that the poorer feed conversion was as a result of wastage. Indeed, Pluske and Williams, (1996) reported that post-weaned pigs had difficulty in adapting to "wet and dry" feeders.

There was no significant effect of feeder type on performance during the finishing period. Walker (1990) and Patterson and Walker, (1989) reported higher intakes and growth rates for finishing pigs offered feed from “wet and dry” single-space feeders and concluded there was a positive design aspect to the single-space feeder which stimulated feed intake and hence improved average daily gain. While there was no significant difference in performance of the pigs fed from the two feeder types, average daily gain and FCR were numerically improved by offering feed from single-space feeders. The greater number of pigs at the feeder and the higher levels of aggression around the feeder suggests that the “wet and dry” single-space feeder led to greater competition and that this actually stimulated pigs to eat (Baxter, 1983). Furthermore, the fact that apparent feed intake was similar for pigs on both feeder types but that average daily gain and FCR were better on the single-space feeder suggests that there was a degree of wastage with the “dry” multi-space feeder (Walker, 1990).

## Conclusions

- The “growth check” at transfer to finishing accommodation is not exacerbated by the change in feeder type.
- Changing feeder type at 10 weeks of age stimulated pigs to eat throughout the finishing period and improved production performance.
- “Dry” multi-space feeders are the optimum feeder choice for pigs between 4 and 10 weeks of age.
- Feeder type has no significant effect in the finishing stage with both “dry” multi-space feeder and “wet and dry” single space feeder resulting in similar performance.
- However, it would appear that there is more wastage with “dry” multi-space feeders in the finishing period and that “wet and dry” single-space feeders may increase feed intake through increased competition.
- The optimum feeding regime suggested in this work involves a change in feeder type from a “dry” multi-space feeder (weeks 4 - 10) to a “wet and dry” single space feeder (weeks 10 - finish) at transfer to finishing accommodation. This provides the optimum feeder type at each stage and the change stimulates pigs to eat thus improving performance.

## Acknowledgements

The authors gratefully acknowledge joint funding for this research from the Pig Production Development Committee in conjunction with the Ulster Farmers’ Union Pigs Committee and the Department of Agriculture and Rural Development for Northern Ireland (DARDNI). The authors also wish to acknowledge the pig unit staff at ARINI for the exceptional care of the animals and diligence when conducting the experiment.

## References

BAXTER M.R. (1983) Feeding and aggression in pigs. *Applied Animal Ethology*, **9**: 74-75.

BILKEI G., TAKACS T.G.T., BIRO O. and BILKEI H. (1997) Influence of frequent moving of pigs among houses on the economics in fattening units. *Deutsche Tierarztliche Wochenschrift*, **104**: 529-531.

EKKEL E.D., VAN DOORN C.E.A., HESSING M.J.C. and TIELEN M.J.M. (1995) The specific-stress-free housing system has positive effects on productivity, health and welfare of pigs. *Journal of Animal Science*, **73**: 1544-1551.

FRASER D., MILLIGAN B.N., PAJOR E.A., PHILIPS P.A., TAYLOR A.A. and WEARY D.M. (1998) Behavioural perspectives on weaning in domestic pigs. In: Wiseman J., Varley M.A., Chadwick J.P. (Eds.), *Progress in Pig Science*, Nottingham University Press, UK, pp. 121-140.

MARDAROWICZ L. (1985) The influence of moving pigs to another building, according to normal commercial procedure, on their health and productivity. Department of Building Technology in Agriculture, Agriculture University of Norway, *IBT-Rapport Number 204.*

O'CONNELL N.E., BEATTIE V.E. and WEATHERUP R.N. (2002) Influence of feeder type on the performance and behaviour of weaned pigs. *Livestock Production Science*, **74**: 13-17.

PATTERSON D.C. and WALKER N. (1989) Observations of voluntary feed intake and wastage from various types of self feed hoppers. In: Forbes J.M., Varley M.A. and Lawrence T.L.J. (eds) *The Voluntary Food Intake of Pigs*. British Society of Animal Production, **13**: 114-116.

PETHERICK J.C. and BLACKSHAW J.K. (1987) A review of the factors influencing the aggressive and agonistic behaviour of the domestic pig. *Australian Journal of Experimental Agriculture*, **27**: 605-611.

PLUSKE J.R. and WILLIAMS I.H. (1996) The influence of feeder type and the method of group allocation at weaning on voluntary food intake and growth in pigs. *Animal Science*, **62**: 115-120.

WALKER N. (1990) A comparison of single- and multi-space feeders for growing pigs fed non-pelleted diets ad libitum. *Animal Feed Science and Technology*, **30**: 169-173.

# PORCINE CIRCOVIRUS 2: VIROLOGY, FIELD DISEASE AND EXPERIMENTAL INFECTIONS

**Gordon M. Allan, Francis McNeilly, Seamus Kennedy and Brian M. Adair**

## Introduction

This communication summarises the work carried out in the last eight years by staff at Veterinary Sciences Division, Department of Agriculture and Rural Development for Northern Ireland (DARDNI), Belfast, in collaboration with colleagues in Europe and North America, on porcine circoviruses (PCVs) and PCV-associated diseases including postweaning multi systemic wasting syndrome (PMWS). This document is not intended to be a comprehensive review of all the PCV2/PMWS literature.

Research projects on PCV2 and PMWS were initiated within DARDNI Science Service in early 1997 and have continued to be funded to date. This funding is consistent with the DARDNI Science Service proactive approach to the investigation of emerging diseases that may threaten the Northern Ireland agri-food industry. In addition, our group has obtained substantial external funding. A European Union (EU) Framework 5 grant on PMWS (QLK2-CT-1999-00445), co-ordinated from VSD with partners from the United States, Canada, Denmark, France, Belgium and Switzerland has just been terminated and a new EU funded project, with 16 international partners will be initiated in September 2004.

## Porcine Circoviruses

Porcine circovirus 1 (PCV1) was first identified in 1974 as a contaminant of the continuous pig kidney cell line PK/15 (Tischer *et al.*, 1974). This virus was later shown to contain a single-stranded, circular DNAgenome and named porcine circovirus. Studies on this virus have, to date, been unable to link it with any field disease. A “novel” PCV-like virus was first isolated from pigs with wasting disease in western Canada in 1998 (Ellis *et al.*, 1998). Shortly thereafter, almost identical viruses to this Canadian isolate were isolated from diseased pigs in North America and Europe (Allan *et al.*, 1998a). Using monoclonal and polyclonal antibodies and genomic sequence analysis these isolates were shown to be antigenically distinct from PCV1 isolates and were designated PCV2 viruses (Allan *et al.*, 1998b; Meehan *et al.*, 1998). Analysis of the genomes of PCV2 from isolates from North America and Europe has shown that they belong to a closely related group exhibiting greater than 96% intra-group nucleotide sequence identity (Meehan *et al.*, 1998). However, comparison of the genomic sequence of PCV2 isolates with the genomic sequence of PCV1 has shown a less than 80%

overall nucleotide sequence identity. PCV1 and PCV2 are small icosahedral, non-enveloped viruses containing a single-stranded, circular DNAgenome and, as such, are now classified in the circovirus genus of the family *Circoviridae.*

## PCV2: Epidemiology

To date, little information has been published in the peer-reviewed literature on laboratory-based epidemiological studies. PCV2 antibody has been demonstrated in pigs throughout the world and retrospective analysis of sera from 1974 has also shown the presence of antibody to a PCV2 virus in a high percentage of the sera tested (Walker *et al.*, 2000; Sanchez *et al.*, 2001a). Seroconversion to PCV2 was demonstrated in pigs on commercial farms between 3 and 4 weeks post weaning (Cottrell *et al.*, 1999) and PCV2 nucleic acid was detected in faeces, urine and blood samples of young pigs on PMWS-affected and PMWS-unaffected farms. Transmission of PCV2 infection from experimentally-infected pigs to seronegative pigs in separate but neighbouring pens has been demonstrated, indicating that aerial transmission of the virus is possible (Charreyre *et al.*, 2000).

PCV2 can be vertically transmitted and has been associated with reproductive disorders in Canada (West *et al.*, 1999) and Denmark (Ladekjaer-Mikkelson *et al.*, 2001), however, PCV2-associated reproductive disorders are uncommon. PCV2 nucleic acid, but not infectious virus has been demonstrated in semen from boars experimentally infected with PCV2. The consequences of sub-clinical vertical transmission, if it occurs, have not, to date been investigated and represent an important gap in the knowledge of PCV2-associated diseases.

## PCV2-associated diseases

Field observations

PCV2 has been associated with a number of disease syndromes in pigs (Allan and Ellis, 2000). An association of a PCV with interstitial pneumonia and lymphadenopathy in a 6 week-old pig in California was reported in 1996. Using a PCV1 generic probe, viral DNA was detected in tissue samples from this pig. Subsequent isolation and characterization of this virus showed it to be PCV2 (Allan *et al.*, 1998b).

A wasting syndrome in Canadian pigs, first identified in 1991 in high health specific pathogen freeherds in Western Canada was first reported in 1996 (Clark, 1997). The authors proposed the term “post-weaning multisystemic wasting syndrome” to describe the clinical condition. PCVnucleic acid and antigen was demonstrated in abundance in the lesions of affected pigs and subsequent isolation and characterization of a PCV2 virus from diseased pigs was reported (Ellis *et al.*, 1998). Also in 1996, workers in France reported a piglet wasting disease, but failed to identify the causal agent. Subsequent investigations on material from affected piglets from northern France identified a PCV2 virus (Allan *et al.*, 1998b). Since these initial reports of PCV2-associated PMWS in piglets in Canada and France in 1996 the disease has been reported in almost all pig producing countries around the world and PCV2 viruses have been isolated from all reported cases. It is of interest to note that the initial outbreaks of PMWS in western Canada were diagnosed in high health herds. These herds are typically free of the major enteric and respiratory diseases that affect swine. PMWS has also been diagnosed in wild boar.

Gross lesions of PMWS include generalised lymphadenopathy, hepatitis, nephritis and pneumonia and typical histological lesions include lymphocytic depletion and multinucleated giant cell formation in lymph nodes, degeneration and necrosis of hepatocytes, and multifocal lymphohistiocytic interstitial pneumonia. PMWS leads to catastrophic effects on performance and dramatically increases mortality in both post-weaned (Figure 1) and finishing pigs (Figure 2).

In addition to PMWS, PCV2 antigen has been demonstrated in abundance in lesions from lungs from pigs with proliferating and necrotising pneumonia, in tissues from pigs with sow abortion and mortality syndrome (SAMS) and in lungs from pigs previously misdiagnosed as having post-weaning porcine reproductive and respiratory syndrome (PRRS) (Allan and Ellis, 2000). PCV2 has also been associated with porcine dermatitis and nephropathy syndrome (PDNS) which, in recent years has reached epidemic proportions in some countries. Although epidemiological evidence strongly suggests that the causes of PMWS and PDNS may be linked, it still remains to be proven that PCV2 is an infectious component of PDNS (Gresham *et al.*, 2000; Meehan *et al.*, 2001). Recent reports from the USA have also identified PCV2 as an important agent in porcine respiratory disease complex (PRDC).

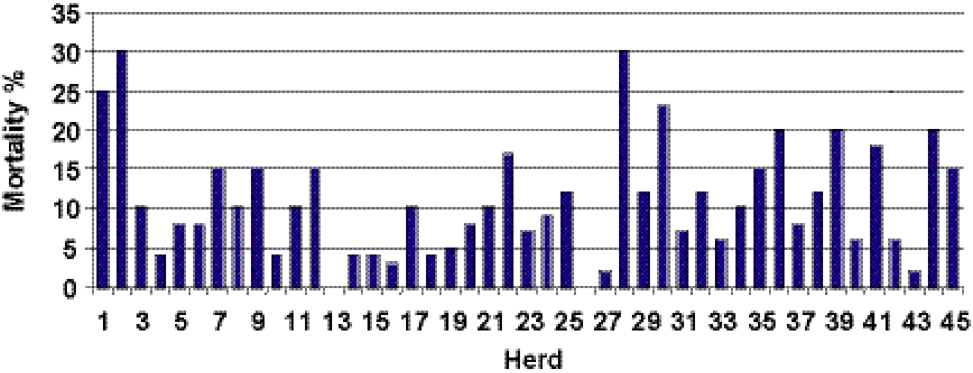


**Figure 1** Post-weaning mortality in PMWS herds

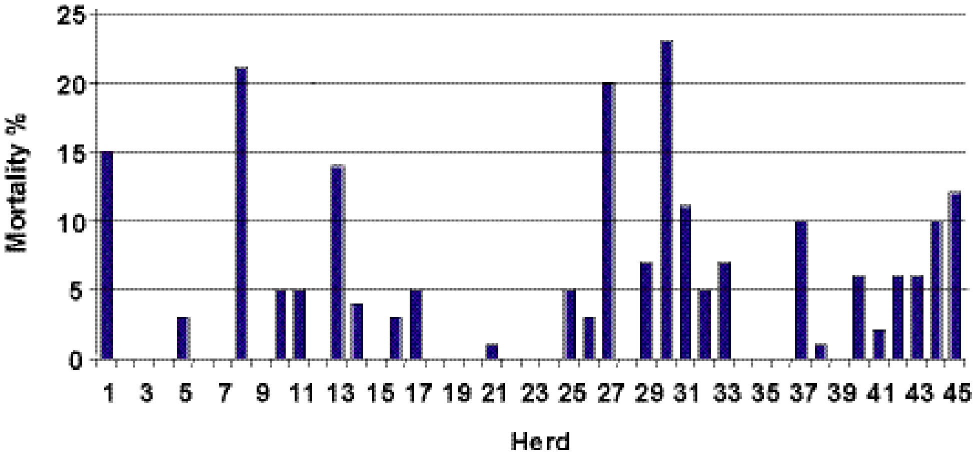


**Figure 2** Finishing pig mortality in PMWS herds

## Experimental observations

Gross and histological lesions consistent with PMWS was first reported in PCV2 and porcine parvovirus (PPV)-experimentally infected gnotobiotic and colostrum deprived (CD) pigs in 1999 (Ellis *et al.*, 1999;. Allan *et al.*, 1999; Kennedy *et al.*, 2000). Pigs inoculated with PPV alone were clinically normal. In dually infected pigs all histological lesions were associated with an abundance of PCV2 antigen and minimal amounts or no PPV antigen (Krakowka *et al.*, 2000). Recent studies in the same gnotobiotic model have shown that inoculation of pigs with PCV2 alone + non-specific stimulation of the inoculates immune system results in clinical PMWS in 100% of the inoculates. The authors concluded that PCV2 was the only causal infectious agent necessary for the development of PMWS. Stimulation of the immune system of young pigs in current husbandry practises can be multifactorial. Exposure to infectious agents is an immunostimulatory event. Mixing of pigs, based on body weight and condition and not on litters, is stressful and stimulates some components of their immune system, as well as exposing them to fresh infectious challenges. The use of highly potent vaccines in young pigs is a specifically designed stimulation to their immune system at an early age and the search and development for more potent, one-shot vaccines continues. Clinical PMWS has now been experimentally reproduced in CD piglets using a PCV2 isolate from clinically normal pigs sacrificed in 1993 and this is the first report of experimental reproduction of the disease with a PCV2 isolate from a sub-clinical infection. The results suggest that the host status or host/environmental interactions may be the important factors in determination of disease outcome following PCV2 infection. Dual infections of CD pigs with PCV2 and PRRS virus have resulted in potentiation of PCV2 replication, leading to PCV2-associated lesions in lungs of inoculates. Pigs in this experiment inoculated with PRRS virus alone, did not have clinical disease or histological lesions in their lungs (Allan *et al.*, 2000).

Recent studies within our EU consortium have demonstrated experimental reproduction of PMWS in 50% of colostrum fed (CF), seronegative piglets inoculated with PCV2 alone at 3 weeks of age (Botner *et al.*, 2001) and colostrum fed, seropositive piglets inoculated with PCV2 alone at seven weeks of age. In addition experimental in-utero infection of porcine foetuses has resulted in gross and histological lesions in the inoculated foetus, that vary in severity, dependent on the state of gestation of the foetus when inoculated (Sanchez *et al.*, 2001b). Of particular importance is the recent report of experimental infections of pigs with an infectious PCV2 cloned plasmid that resulted in gross and histological lesions consistent with PMWS (Halbur, 2001).

## Diagnosis

Currently laboratory diagnosis of PCV2-associated diseases should always include the demonstration of PCV2 antigen or nucleic acid in association with lesions (McNeilly *et al.*, 2001). Diagnosis should not be carried out by non-quantitative PCR. The current expansion of disease syndromes associated with PCV2 and the previously misdiagnosed PCV2 associated disease cases may be attributed to an absence of thorough multidisciplinary diagnostic investigations. Experimental studies within our group have indicated that the use of quantitative, real time PCR may have future applications as a diagnostic tool. A PCV2-specific antibody detecting enzyme linked immunosorbent assay (ELISA) is available for pigs and other species (Walker *et al.*, 2000). However, this is of limited use as a diagnostic as surveys have shown that antibody to a PCV2 virus is widespread in the pig population around the world. Sub-clinical infections with PCV2 are commonplace.

## Control of PCV2-associated diseases

Currently very little is known about control of PCV2-related diseases. Prevention of the introduction of PMWS onto a farm is best achieved by a careful consideration of the merits of the introduction of "new" practises, biologicals, breeding stock, feeding regimes to a PMWS free herd and the maintenance of good biosecurity.

Recent field studies in France have indicated that a "20-point plan" of improved husbandry measures can limit the disease impact, but not eliminate it. Details of these procedures include changes to batch farrowing and initiation of "all in all out" systems, changes in nutritional composition and feeding regimes, changes in husbandry practises that minimise stress and introduction of infections and changes in weaning and post weaning practises.

PCV2 is highly resistant to inactivation by common detergents and disinfectants, making decontamination of infected premises difficult. Serotherapy procedures using donor pigs have, in the past, been carried out in England and other EU countries with mixed success and serotherapy as a treatment for PMWS has now been discontinued in many EU countries, including Great Britain.

Vaccination of piglets with candidate PCV2 vaccines has shown protection from development of clinical disease, but not infection, following challenge at 7 weeks of age. Limited field trials with candidate vaccines are presently being planned and it is hoped a PCV2 vaccine will soon be available.

## PCV2:The future

Our understanding of PCV2-associated diseases has advanced in the last few years, however a number of important questions still remain to be answered. It is amazing that, to date, we have not identified the primary site of replication of PCV2 in pigs, nor do we know the mechanism/s of potentiation of PCV2 replication following immunostimulation. In addition, we still do not know if sub-clinical vertical transmission occurs, and if it does, how that affects the eventual clinical condition of the pig. We have no information on serological differences between PCV2 isolates (if they exist), age resistance to disease associated with PCV2 infections or the role of pig genetics in the susceptibility of pigs to PCV2-associated disorders.

More research is needed in these areas if we are to fully understand PCV2 interactions with the pig and, in particular the pig immune system.

## References

ALLAN G.M. and ELLIS J.A. (2000) Porcine circoviruses: a review. *Journal of Veterinary Diagnostic Investigation*, **12**: 3-14.

ALLAN G.M., McNEILLY F., KENNEDYS., DAFTB., CLARK E.G., ELLIS J.A., HAINES D.M., MEEHAN B.M. and ADAIR B.M. (1998a) Isolation of porcine circovirus-like viruses from pigs with a wasting disease in the United States of America and Europe. *Journal of Veterinary Diagnostic Investigation*, **10**: 3-10.

ALLAN G.M., KENNEDY S., McNEILLY F., FOSTER J.C., ELLIS J.A., KRAKOWKA S.J., MEEHAN B.M. and ADAIR B.M. (1999) Experimental reproduction of severe wasting disease by co-infection of pigs with porcine circovirus and porcine parvovirus. *Journal of Comparative Pathology*, **121(1)**: 1-11.

ALLAN G.M., McNEILLY F., ELLIS J.A., KRAKOWKA S.J., MEEHAN B.M., McNAIR, I., WALKER, I. and KENNEDY S. (2000) Experimental infection of colostrum deprived piglets with porcine circovirus (PCV2) and porcine reproductive and respiratory syndrome virus (PRRSV) potentiates PCV2 replication. *Archives of Virology*, **145**: 2421-2429.

ALLAN G.M., MEEHAN B., TODD D., KENNEDY S., McNEILLY F., ELLIS J., CLARK E.G., HARDING J., ESPUNAE., BOTNER A. and CHARREYRE C. (1998b) Novel porcine circoviruses form pigs with wasting syndromes. *Veterinary Record*, **142**: 467-468.

BOTNER A., LADEKJAER-MIKKELSON A-S., NIELSON L., KRAKOWKA S.J., ELLIS J.A., McNEILLY F., ALLAN G.M. and STORGAARD T. (2001) Reproduction of PMWS in immunostimulated and non-immunostimulated conventional 3-week-old piglets experimentally infected with PCV2. *International Conference on ssDNA viruses of Plants, Birds, Pigs and Primates, St. Malo, France*.

CHARREYRE C., BOEUF L., BRUNET S. and REYNAUD G. (2000) Natural transmission of PCV2 in seronegative 9-week-old pigs. *Proceedings of the 16th IPVS, Melbourne, Australia*, pp. 630.

CLARK E.G. (1997) Post weaning multisystemic wasting syndrome. *Proceedings of the American Association of Swine Practitioners,* **28**: 499-501.

COTTRELL T.S., FRIENDSHIPR.M., DEWY C.E., ALLAN G.M., WALKER I. and McNEILLY F. (1999) A study investigating epidemiological risk factors for PCV2 in Ontario. *The Pig Journal*, **44**: 10-17.

ELLIS J., HASSARD L., CLARK E., HARDING J., ALLAN G., WILSON P., STROKAPPE J., MARTIN K., McNEILLY F., MEEHAN B., TODD D. and HAINES D. (1998) Isolation of circoviruses from lesions from pigs with post weaning multisystemic wasting syndrome. *Canadian Veterinary Journal*, **39**: 44-51.

ELLIS J.A., KRAKOWKA S., LAIRMORE M., HAINES D., BRATNICH A., CLARK E., ALLAN G., KONOBY C., HASSARD L., MEEHAN B., MARTIN K., KENNEDY S. and McNEILLY F. (1999) Reproduction of lesions of postweaning multisystemic wasting syndrome in gnotobiotic piglets. *Journal of Veterinary Diagnostic Investigation*, **11**: 3-14.

GRESHAM A., JACKSON G., GILES N., ALLAN G., McNEILLY, F. and KENNEDY S. (2000) PMWS and porcine nephropathy syndrome in Great Britain. *Veterinary Record*, **146**: 143.

HALBUR P. (2001) PMWS: Improved models and recent findings of clinical significance. *Proceedings of the Swine Disease Conference for Swine Practitioners*, November 2001, Ames, Iowa: 162-166.

KENNEDY S., MOFFETT D., McNEILLY F., MEEHAN B., ELLIS J., KRAKOWKA S. and ALLAN G.M. (2000) Reproduction of lesions of postweaning multisystemic wasting syndrome by infection of conventional pigs with porcine circovirus type 2 alone or in combination with porcine parvovirus. *Journal of Comparative Pathology*, **122** (1): 9-24.

KRAKOWKA S., ELLIS J.A., MEEHAN B., KENNEDY S., McNEILLY, F. and ALLAN G. (2000) Viral wasting syndrome of swine: experimental reproduction of post weaning multisystemic wasting syndrome in gnotobiotic swine by co-infection with porcine circovirus 2 and porcine parvovirus. *Veterinary Pathology*, **37**: 254-263.

LADEKJAER-MIKKELSON A.S., NIELSON J., STORGAARD T., BOTNER A., ALLAN G. and McNEILLY F. (2001) A field case of transplacental infection with PCV2 associated with reproductive failure. *Veterinary Record*, **148**: 759-760.

McNEILLY F., McNAIR I., MACKIE D.P., MEEHAN B.M., KENNEDY S., MOFFETT D., KRAKOWKA S. and ALLAN G.M. (2001) Production, characterisation and applications of monoclonal antibodies to porcine circovirus 2. *Archives of Virology*, **146(5)**: 909-922.

MEEHAN B.M., McNEILLY F., McNAIR I., WALKER I., ELLIS J.A., KRAKOWKA S. and ALLAN G.M. (2001) Isolation and characterisation of porcine circovirus type 2 from cases of sow abortion and porcine dermatitis and nephropathy syndrome. *Archives of Virology*, **146 (4)**: 835-842.

MEEHAN B.M., McNEILLY F., TODD D., KENNEDY S., JEWHURST V.A., ELLIS J.A., HASSARD L.E., CLARK E.G., HAINES D.M. and ALLAN G.M. (1998) Characterisation of novel circovirus DNAs associated with wasting syndromes in pigs. *Journal of Gen. Virology*, **79**: 2171-2179.

SANCHEZ R., NAUWYNCK H.J. and PENSAERT M.B. (2001a). Serological survey of porcine circovirus type 2 antibodies in domestic and feral pig populations in Belgium. *International Conference on ssDNA Viruses of Plants, Birds, Pigs and Primates*, St. Malo, France.

SANCHEZ R.E., NAUWYNCK H.J., McNEILLY F., ALLAN G.M. and PENSAERT M.B. (2001b) Porcine circovirus 2 infection in swine foetuses inoculated at different stages of gestation. *Veterinary Microbiology*, **83(2)**:169-176.

TISCHER I., RASCH R. and TOCHTERMANN G. (1974) Characterisation of papaovavirus and picronavirus like particles in permanent pig kidney cell lines. *Zbl. Bakteriol. Paraseitenkd. Infektionskr. Hyg. Abt. 1. Orig.*, 26: 153-167.

WALKER I.W., KONOBY C.A., JEWHURST V.A., McNAIR I., McNEILLY F., MEEHAN B.M., COTTRELL T.S., ELLIS J.A. and ALLAN G.M. (2000) Development and application of a competitive enzyme-linked immunsorbent assay for the detection of serum antibodies to porcine circovirus type 2. *Journal of Veterinary Diagnostic Investigation*, **12**: 400-405.

WEST K.H., BYSTROM J.M., WOJNAROWICZ C., SHANTZ N., JACOBSEN M., ALLAN G.M., HAINES D.M., CLARK E.G., KRAKOWKAS.J., McNEILLYF., KONOBYC.A., MARTIN K. and ELLIS J.A. (1999). Myocarditis and abortion associated with intrauterine infection of sows with porcine circovirus 2. *Journal of Veterinary Diagnostic Investigation*, **11**: 530-532.

# ACCURACY OF ULTRASONIC INSTRUMENTS TO PREDICT BACKFAT DEPTH

**Elizabeth Magowan and M. Elizabeth E. McCann**

## Introduction

In Northern Ireland the grading system for, and hence the value of, pork carcasses is derived from the weight of the hot carcass and the depth of backfat 65 mm from the edge of the dorsal mid-line at the level of the last rib i.e. the $P_2$ position (Figure 1).

The $P_2$ measurement is taken in the factory on the hot carcass using the Ulster Probe, which is calibrated daily using an Optical probe. On farm, the $P_2$ measurement can be taken on live pigs using several ultrasonic instruments. Although these ultrasonic devices can be used to gauge the depths of backfat on finished pigs, they are mainly used in the selection of breeding stock, both boars and gilts (Lindhé *et al.*, 1980). In addition, since the heritability value of backfat depth is relatively high, between 0.4 and 0.6 (Whittemore, 1993) the production of leaner pigs through genetic selection is achievable. Indeed, this has been demonstrated at Pig Industry Genetics (PIG) throughout the last 30 years as average $P_2$ values have decreased from 14 mm to 6.6 mm (PIG, 2000).

In order for genetic selection to be effective in reducing backfat thickness, ultrasonic instruments must not only be consistent in their measurement, but also consistent and equal with the results attained using the Ulster and Optical probes on the carcass in the factory. Within the literature, some research has focused on the accuracy of ultrasonic instruments in the prediction of fat depth and lean meat in the carcasses of pigs (Sather *et al.*, 1982; Greer *et al.*, 1987; Kanis *et al.*, 1986). However results are not conclusive between reports and no particular ultrasonic device is considered best. In addition, when investigating approved Optical probes used in factories in Canada, Pomar and Marcoux (2003) reported that the Hennessy and Destron grading probes gave significantly different lean yield prediction values which resulted in some producers being paid less than others for pigs that may have contained equal yields of lean meat.

The primary aim of this study was to assess the accuracy of two common ultrasonic instruments used both in the selection of breeding stock and in the prediction of the factory value of $P_2$, as measured by the Ulster and Optical probes.

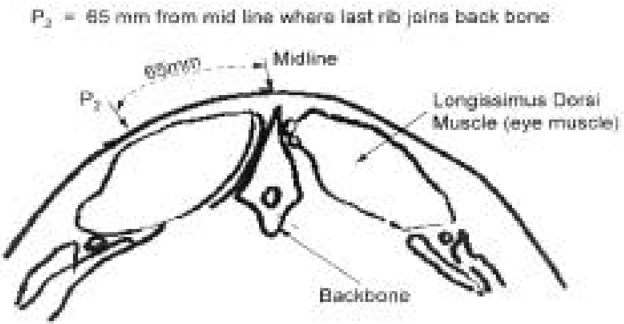


**Figure 1** Cross section at last rib

## Materials and Methods

A total of one hundred and twenty pigs were assessed (60 boars and 60 gilts) over 6 replicates (average weight 99.5 kg ± 4.10 kg). Prior to slaughter, all pigs were housed in groups of 20 and balanced for weight and gender. For ten weeks prior to slaughter they were offered a finishing diet *ad libitum* (composition, g/kg): barley 564, wheat 100, soyabean meal 230, soya oil 30, molaferm 30, water 20, BP VMC 25, lysine 1.5. All pigs were 152 days (± 2) at slaughter.

On the day prior to slaughter, the depth of backfat at the $P_2$ position was measured at ARINI, using two hand-held ultrasonic instruments namely the SFK Pig Scan-A-Mode backfat Scanner (SFK) and the Meritronics A-Mode Pulse Echo Ultrasonic Machine (Meritronics). Each animal was confined in a weighbridge, where their weight was recorded, and the $P_2$ position was located and marked with indelible ink. This point was shaved and coupling gel (Ultrasound Gel, SCAN) applied to ensure good contact between the probe and the pig. The right side of the animal was used to correspond to the measurement taken using the Ulster and Optical probes at the factory. The marked $P_2$ position was not identified by factory personnel and therefore did not influence any measurements taken at the factory.

On the day of slaughter the depth of backfat at $P_2$ was measured by factory personnel on the hot carcass using the Ulster probe (Ulster) and by personnel from Quality Assurance Branch, Department of Agriculture and Rural Development (DARD) using the Optical probe (Optical).

The depth of backfat was again measured at the $P_2$ position on the day after slaughter on the chilled carcass using a Calliper via dissection methods (Dissection).

Statistical differences between the various methods of measurements were tested by analysis of variance (ANOVA) and by regression analysis. Finish weight was used as a covariate.

## Results

### Mean values of $P_2$ obtained by the different probes

There was no significant difference in the $P_2$ values attained when the Ulster, Optical and the SFK ultrasonic probes were used (Table 1). However the $P_2$ value obtained when the Meritronics ultrasonic probe was used was significantly different from that obtained when the SFK or the Ulster probe was used (Table 1).

**Table 1** Mean, minimum and maximum backfat depth values (mm) at $P_2$ obtained from the five methods of measurements

| | Mean | Minimum | Maximum | Standard Deviation |
|---|---|---|---|---|
| SFK | $11.67^{c}$ | 8.5 | 17.7 | 2.03 |
| Meritronics | $10.98^{ab}$ | 7.0 | 17.0 | 2.09 |
| Ulster | $11.57^{c}$ | 7.0 | 19.0 | 2.38 |
| Optical | $11.39^{bc}$ | 8.0 | 18.0 | 2.41 |
| Dissection | $10.44^{a}$ | 6.7 | 17.0 | 2.32 |
| SEM | 0.196 | | | |
| P | <0.001 | | | |

Numbers with the same superscript are not significantly different

### Regression correlations between the values attained from the different probes

Significant positive correlations ($P<0.001$) were determined between the values obtained using the various methods of measuring backfat depth at $P_2$ (Table 2). There were strong relationships between the values attained for $P_2$ by the two ultrasonic instruments ($r = 0.924$) (Figure 2) and by the Ulster and Optical probes ($r = 0.938$) (Figure 3). A weaker relationship (although significant ($P<0.001$)) was determined between the values of $P_2$ as measured by the Ulster probe and the Meritronics instruments ($r = 0.831$) than that determined between the Ulster and the SFK ($r = 0.844$) (Table 2).

**Table 2** The regression coefficients (r) between the $P_2$ values (mm) attained from the five methods of measurements

| | SFK | Meritronics | Ulster | Optical | Dissection |
|---|---|---|---|---|---|
| **SFK** | - | 0.924 | 0.844 | 0.869 | 0.837 |
| **Meritronics** | - | - | 0.831 | 0.859 | 0.811 |
| **Ulster** | - | - | - | 0.938 | 0.869 |
| **Optical** | - | - | - | - | 0.877 |
| **Dissection** | - | - | - | - | - |

All correlations were significant (P<0.001)

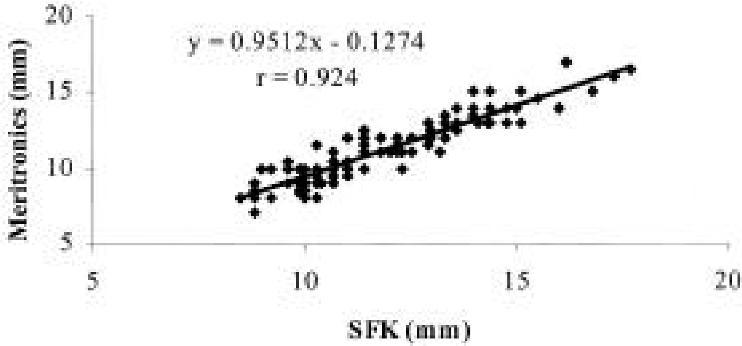


**Figure 2** Correlation between the $P_2$ (mm) values obtained using the SFK and the Meritronics instruments

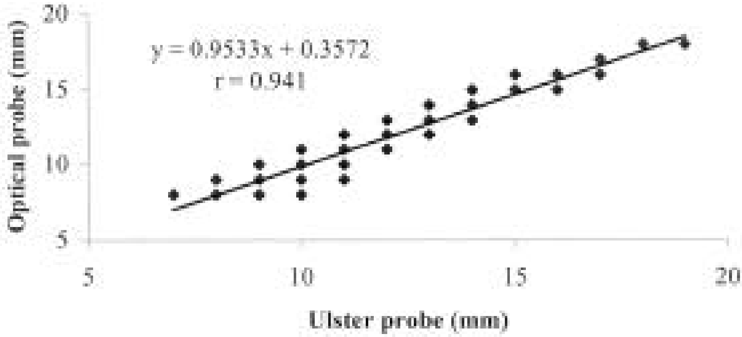


**Figure 3** Correlation between the $P_2$ (mm) values obtained using the Ulster and Optical probes

## Effect of sex on the mean values of $P_2$ obtained by different probes

The depth of backfat at $P_2$ was significantly ($P<0.01$) lower for boars than for gilts with an average difference of 1.2 mm (Table 3). For both sexes the method of dissection gave the lowest reading of $P_2$ with the Meritronics ultrasonic measurement giving a slightly higher value than when dissection was used and lower than the remaining 3 methods (Table 4). There was no significant sex x probe interaction on the ability of the various methods of assessment to measure $P_2$.

**Table 3** Mean backfat depth (mm) at $P_2$ averaged for all the methods of measurement for boars and gilts

| | **$P_2$ (mm)** |
|---|---|
| Boars | 10.61 |
| Gilts | 11.81 |
| SEM | 0.259 |
| P | <0.01 |

**Table 4** Mean backfat depth values (mm) at $P_2$ for the different methods of measurements for boars and gilts

| | **Boars** | | **Gilts** | |
|---|---|---|---|---|
| | **Mean** | **Standard Deviation** | **Mean** | **Standard Deviation** |
| SFK | 11.29[c] | 1.80 | 12.06[c] | 2.16 |
| Meritronics | 10.68[b] | 1.77 | 11.27[ab] | 2.21 |
| Ulster | 11.27[c] | 2.39 | 11.88[c] | 2.30 |
| Optical | 11.05[cb] | 2.39 | 11.73[bc] | 2.38 |
| Dissection | 10.03[a] | 2.18 | 10.85[a] | 2.32 |
| SEM | 0.246 | | 0.288 | |
| P | <0.001 | | <0.001 | |

Numbers with the same superscript are not significantly different

## Discussion

In general two types of probe are used to measure the amount of backfat in pigs - optical type probes and ultrasonic type probes. Optical probes are the main type used in the prediction of backfat depth on hot carcasses in the factory. They work on the principle that there is a difference in the reflectance of light between muscle tissue and fat which subsequently gives a reading of the depth of fat (Kempster *et al.*, 1981; Pomar *et al.*, 2002). Different countries have adopted different types of optical probe for use in their classification system of pig carcasses and ultimately the prediction of percentage lean meat from the carcass. Researchers have subsequently compared the accuracy and predictability of these probes against each other. Following a review of the literature, Scheper *et al.*, (1983) (cited by Glodek, 1989) commented that the German derived SKG probe was no better at predicting backfat depth than the Danish Fat-O-Meter or the New Zealand sourced Hennessy grading probe. Kempster *et al.*, (1985) subsequently reported that although the Danish Fat-O-Meter probe was slightly better than the Hennesy grading probe there was no major difference. Later work by Pomar *et al.*, (2001) found that the Hennessy probe tended to over-predict backfat and under-predict muscle depth when compared to data collected from digitalised images. In further work by Pomar and Marcoux (2003) they found that, compared to the Hennessy grading probe, the Destron grading probe predicted even lower lean meat yields. In Northern Ireland the Ulster probe, developed by the Wolfson Opto-Electronics Unit at the Queen's University of Belfast, is used as the main probe in the measurement of backfat of hot carcasses of pigs. The Ulster probe is calibrated daily with a simple Danish Optical probe. In comparison with the Danish optical probe, Kempster and Evans, (1979) and Kempster *et al.*, (1981) found that the Ulster probe underestimated backfat depth by 1.2 and 1.8 mm respectively.

In the present study it was anticipated that the measurement of backfat depth via dissection would provide a conclusive result for backfat depth from which the measurements using the Ulster, Optical and Ultrasonic probes could be related. However after chilling, backfat depth, together with the carcass as a whole, is reduced in volume i.e. shrinkage occurs, due to drip loss and the reduction in temperature from body heat of 37ºC to storage temperature of approximately 3ºC. Although good correlations existed between the values attained from the dissection method and the other methods they were consistently lower, as a result of shrinkage. The result obtained after dissection cannot therefore be used as the conclusive value of backfat depth of the hot carcass. Consequently values obtained from the other measurements are compared with each other rather than with a true measure of actual backfat depth at the time of slaughter. In addition, Kempster and Evans, (1979) and

Kempster *et al.*, (1981) argued that the absolute level of fat thickness predicted by the different instruments is not particularly important, provided the instruments are calibrated against one another when used in the same classification scheme. Therefore, it could be argued that the compatibility and consistency of accuracy of the instruments used in NI to measure backfat depth on live and slaughtered pigs is more important than the actual measurement of backfat, since price is related to the outcome of the Ulster probe assessment. In the present study, a robust correlation (Table 2) and similar mean values (Table 1) were found when the Ulster and Optical probes were used. However this would be expected, as the Ulster probe is calibrated daily with the Optical probe. It does however reassure producers that the values attained using the Ulster probe are consistent and highly correlated to the values attained using the Optical probe. The measurement made using the Ulster probe in the abattoir was not influenced by the indelible ink mark as this mark was only visible after close inspection.

Ultrasonic probes are mainly used to predict the depth of backfat on live pigs and hence are predominately used in the selection of breeding stock. Ultrasonic probes operate in a similar manner to optical probes where electronic waves or pulses are used to detect reflectance as opposed to light. Again there are several models of these devices available and their accuracy and predictability has also been investigated often resulting in conflicting results which will be discussed later. The two most commonly used ultrasonic probes in Northern Ireland include the SFK and Meritronics ultrasonic probe. The work reported here aimed to evaluate the accuracy and relationship of the values attained when these ultrasonic probes were used on live pigs with the values attained in the factory using the Ulster and Optical probes. In agreement with Hawe, (1994), the results suggested that the SFK instrument gave a good indication of the depth of subcutaneous fat at the $P_2$ location on carcasses. Hawe, (1994) also found that there were no differences in the readings obtained by the Meritronics and SFK ultrasonic probes and those attained in the abattoir. However, in the current study, which included a greater number of pigs (120 vs 24), it was observed that the Meritronics ultrasonic probe underestimated the depth of backfat on the carcass at $P_2$, but gave readings which were similar to those attained when measurements of backfat were taken on the chilled, shrunk carcass (Table 1). Although the Meritronics probe under-predicted backfat depth the correlations attained between the ultrasonic probes and the factory probes were moderately robust (Table 2). Therefore although an equation could be used to transpose the values attained by the Meritronics probe, the SFK is a better predictor of backfat depth on the carcass of the pig as measured by the factory probes. In addition values attained when the ultrasonic probes were used had a lower standard deviation than the values attained from factory measurements (Table 1). This suggests that the Ultrasonic probes could not measure the extreme backfat depths which the factory probes recorded, on the other hand it could also be suggested that the factory probes were less accurate since a greater standard deviation can indicate a lower accuracy. Additional investigations are required to clarify the range of backfat depths over which the instruments can measure accurately.

In agreement with other workers (Sather *et al.*, 1982; Davies *et al.*, 1986) results of the current study suggest that gilts, at the same age and weight, were fatter than boars, with the average difference being approximately 1.2 mm (Table 3). The results also indicated that the sex of the pig did not influence the outcome of the probe, since similar trends were apparent when the sexes were mixed (Table 1) or split (Table 4). This is in agreement with Davies *et al.,* (1986) who concluded that the measure of fat depth was not affected by the sex of the pig.

Some researchers have reported that operator can have a larger impact on the outcome of the probe than the probe type (Sather *et al.*, 1982), although Perkins *et al.,* (1992) found no operator effects when using an Aloka 500 real-time diagnostic ultrasonic device. Nevertheless, in order to eliminate any chance of variation due to operator effects in this study the measurements using the SFK and Meritronics ultrasonic instruments were taken by only one operator. A trained operator took all the Optical probe measurements and dissection measurements. Within the factory several operators took measurements using the Ulster probe. However, since a good correlation was found between the values attained using the Optical and Ulster probe it can, therefore, be concluded that operator effects at the factory were minimal.

While $P_2$ is currently the site which is used to estimate carcass lean content, there is some controversy over the accuracy of this assumption. Davies *et al.,* (1986) noted that the subcutaneous fat cover on the pig can be considered a ‘coat’of similar length and circumference but of varying thickness. The weight of subcutaneous fat will therefore vary in direct proportion to the thickness. They added that since the subcutaneous fat is predominately the greatest depot of fat in the pig, the thickness of the layer would therefore be directly proportional to the weight of fat in the pig and hence the amount of lean meat in the pig. In contrast Kanis *et al.,* (1986) concluded that no single backfat measurement position, or combination of positions, was uniformly the best at predicting lean percentage of the pig. Furthermore, McCann and Beattie (2004) reported that $P_2$ value was weakly related to such parameters as eye muscle area and depth and percentage of fat in a chop ($R^2$ <0.3). There is therefore a need to consider other positions and measurements, which may be a more accurate reflection of leanness than solely backfat at the $P_2$ position. This is an important challenge for future research programmes.

## Conclusions

- The SFK probe gave an accurate measure of the depth of backfat at $P_2$ whereas the Meritronics underestimated the depth of backfat at $P_2$ when compared to the measurements attained on hot carcass using the Ulster and Optical probes. A strong correlation was however observed between the values attained from the two ultrasonic instruments.
- The values attained when using the Ulster and Optical probes were similar and correlated strongly.
- It was concluded that, at a similar weight and the same age, boars are leaner than gilts. The sex of the pig however had no effect on the outcome of the method of measurement

## Acknowledgements

The authors gratefully acknowledge joint funding for this research from the Pig Production Development Committee in conjunction with the Ulster Farmers' Union Pigs Committee and the Department of Agriculture and Rural Development for Northern Ireland (DARDNI). The authors also wish to acknowledge the assistance given by the Quality Assurance Branch, DARDNI, in particular Mr Leslie Hamilton and Mr Jim Freeburn, Pig Industry Genetics, especially Mr Leslie Newitt and also the pig unit staff at ARINI for their unfailing assistance and conscienous input.

## References

DAVIES A.S., PEARSON G. and CARR J.R. (1986) Effects of feeding level, protein level, and sex of pig on carcass fatness measured by dissection and optical probe methods. *New Zealand Journal of Experimental Agriculture*, **14**: 301-306.

GOLDEK P. (1989) Methods and equipment for estimating carcass lean content in European countries. In: *The production of pig meat in Mediterranean countries*, Proceedings of the Belgrade Seminar, France 171-177.

GREER E.B., LOWE T.W. and GILES L.R. (1987) Comparison of ultrasonic measurement of backfat depth on live pigs and carcasses with a digital recording instrument. *Meat Science*, **19**: 111-120.

HAWE M. (1994) To determine the accuracy of three hand-held ultrasonic devices for measuring the depth of subcutaneous fat on live pigs. *Pig and Poultry Technology and Development Service - Technology report, PPTDS.*

KANIS E., STEEN H.A.M., VAN DER ROO F., DE GROOT P.N.DE. (1986) Prediction of lean parts and carcass price from ultrasonic backfat measurements in live pigs. *Livestock Production Science*, **14**: 55-64.

KEMPSTER A.J., CHADWICK J. P. and JONES D. W. (1985) An evaluation of the Hennessy grading probe and the SFK Fat-O-Meater for use in pig grading classification and grading. *Animal Production*, **40**: 323-329.

KEMPSTER A.J. and EVANS D.G. (1979) A comparison of different predictors of the elan content of pig carcasses. *Animal Production,* **28**: 87-96.

KEMPSTER A.J., CHADWICK J.P., JONES D.W. and CUTHBERTSON A. (1981) An evaluation of the Hennessy and Chong fat depth indicator and the Ulster probe for use in pig carcass classification and grading. *Animal Production*, **33**: 319-324.

LINDÉ B., AVERDUNK G., BRASCAMP E.W., DUNIEC H., GALJIÉ I.M., LEGAULT C and STEANE D. (1980) Estimation of breeding value in pigs. Report of a working group of the commission on animal genetics. *Livestock Production Sciences,* **7**: 269-282.

McCANN M.E.E. and BEATTIE V.E. (2004) The effects of sire type on reproduction, production performance and carcass quality of pigs. A report prepared for Pig Production and Development Committee.

PERKINS T.L., GREEN R.D., HAMLIN K.E., SHEPARD H.H. and MILLER M.F. (1992) Ultrasonic prediction of carcass merit in beef cattle : evaluation of technician effects on ultrasonic estimates of carcass fat thickness and longissimus muscle area. *Journal of Animal Science*, **70**: 2758-2765.

PIG (2000) *Production sheets from the Northern Ireland Pig Testing Station*. Pig Industry Genetics Co. Ltd.

POMAR C. and MARCOUX M. (2003) Comparing the Canadian pork lean yields and grading indexes predicted from grading methods based on Destron and Hennessey probe measurements. *Canadian Journal of Animal Science*, **83**: 451-458.

POMAR C., FORTIN A. and MARCOUX M. (2002) Successive measurements of carcass fat and loin muscle depths at the same site with optical probes. *Canadian Journal of Animal Science*, **82**: 595-598.

POMAR C., RIVEST J., BAILLEUL P.J.D. and MARCOUX M. (2001) Predicting loin-eye area from ultrasound and grading probe measurements of fat and muscle depths in pork carcasses. *Canadian Journal of Animal Science*, **81**: 429-434.

SATHER A.P., FREDEEN H.T. and MARTIN A.H. (1982) Live animal evaluation of two ultrasonic probes as estimators of subcutaneous backfat and carcass composition in pigs. *Canadian Journal of Animal Science*, **62**: 943-949.

WHITTEMORE C.T. (1993) *The Science and Practice of Pig Production*. Longman Scientific and Technical, Longman, UK.

# INVESTIGATIONS INTO OPTIMUM REGROUPING STRATEGIES FOR PIGS

**Niamh E. O'Connell, Violet E. Beattie and Dennis Watt**

## General introduction

Animal welfare legislation is having an increasingly important effect on the way in which pig production systems are operated. For example, recent amendments to European Union pig welfare legislation mean that producers across Europe will have to adopt group housing systems for sows in the coming years. The European Commission are currently compiling a report to be submitted to the European Council in 2008, which includes information on 'methods of regrouping pigs' and 'further developments of group housing systems for pregnant sows' (Council Directive 2001/88/EC). This suggests that future pig welfare legislation will concentrate to an even greater extent on social requirements of pigs.

Research must be pre-emptive in terms of identifying regrouping strategies that optimise pig welfare. This is particularly important for sows, where welfare problems persist within group housing systems. However, research should also consider industry requirements. For example, regrouping strategies must be practical to implement for the producer, and must lead to optimum productivity and health of the pigs. In addition, regrouping strategies for fattening pigs should aim to meet processor requirements in terms of reducing variability of the final product (Walker, 2002).

The current paper describes two separate studies into regrouping strategies for pigs. The first study investigated regrouping strategies aimed at reducing within-group variation in slaughter weight of fattening pigs. The second study investigated methods of reducing welfare problems faced by sows following mixing in large dynamic groups.

### Study 1 - Strategies for regrouping growing and finishing pigs

## Introduction

Many producers now keep weaned pigs in the same group from weaning until slaughter in order to minimise stress and labour associated with regrouping. However, this practice may lead to high within-group variation in slaughter weight. This, in turn, can lead to inefficient use of space in finishing accommodation. This is due to the fact that some pigs in the group will reach slaughter weight well before others, thus leaving pens half-empty. In addition, in cases where entire groups of pigs are sent for slaughter simultaneously, then increased variability in slaughter weight will result in increased variability in carcass characteristics (Walker, 2002).

It may be possible to reduce within-group variation in slaughter weight through forming uniform weight groups when pigs are being regrouped. However, earlier work suggests that social factors will result in some pigs growing faster than others (O'Connell and Beattie, 1999), thus eliminating the effect of forming uniform weight groups. In addition, chronic aggression associated with unresolved dominance relationships within uniform weight groups (Anderson *et al.*, 2000) may have a negative effect on growth performance (Stookey and Gonyou, 1994).

The aim of the current study was to assess the effect of creating uniform weight groups at weaning at 4 weeks of age on performance during the growing and finishing periods, and on within-group variation in slaughter weight and carcass parameters. An equal number of pigs were also regrouped at the start of the finishing period, at 10 weeks of age, in order to assess whether forming uniform weight groups at this stage had additional benefits in terms of reducing variation in slaughter weight. In addition, the effect of regrouping pigs at 10 weeks of age on mean performance and aggressive behaviour was also assessed.

## Material and methods

### Treatments

One thousand two hundred pigs were assigned to one of the following five treatments:

1. Uniform weight groups formed at weaning and retained until slaughter
2. Mixed weight groups formed at weaning and retained until slaughter
3. Uniform weight groups formed at the start of the finishing period and retained until slaughter
4. Mixed weight groups formed at the start of the finishing period and retained until slaughter
5. Mixed weight groups formed at weaning and mixed at the start of the finishing period to form mixed weight groups, which were retained until slaughter (used to assess the effect of regrouping at 10 weeks of age when compared with Treatment 2)

Three groups of ten pigs were assigned to each treatment. In the case of uniform groups, these consisted of one group of small pigs, one group of medium pigs and one group of large pigs. In the case of mixed weight groups, these consisted of three groups each containing equal numbers of small, medium and large pigs.

Pigs were weaned at 4 weeks of age at an average weight of 9.7 kg. The average weight of small, medium and large groups at 4 weeks of age was 7.9, 9.7 and 11.4 kg, respectively. Mixed weight groups had an average weaning weight of 9.8 kg. Groups formed at 10 weeks of age had an average weight of 30.2 kg. The average weight of small, medium and large groups formed at 10 weeks of age was 25.7, 30.8 and 34.5 kg, respectively. Mixed weight groups formed at 10 weeks of age had an average weight of 30.1 kg. Within-group range in body weight in uniform and mixed weight groups formed at either 4 or 10 weeks of age is presented in Tables 1 and 2. Each group was balanced for gender. Pigs moved to finishing accommodation at 10 weeks of age and were slaughtered at 21 weeks of age.

## Housing

During the growing phase from 4 to 10 weeks of age, pigs were housed in combined stage 1/stage 2 accommodation with plastic slatted floors and a space allowance of 0.38 $m^2$ per pig. One “dry” multi space feeder and a separate drinking bowl was provided per group. Temperature was 28°C for the first day post weaning, and was then reduced by 0.5°C per day to 19°C where it remained for the remainder of the growing period.

At 10 weeks of age, pigs were transported a distance of approximately 1 km to finishing accommodation. Transportation took place between 0900 and 1100 hours. During the finishing period pigs were housed on fully slatted floors at a space allowance of 0.61$m^2$ per pig. Each group of pigs was fed from one single-space feeder supplying both feed and water. Throughout the experimental period, pigs were offered standard pelleted diets on an *ad libitum* basis.

## Parameters measured

Pigs were individually weighed at weaning at 4 weeks of age, and at 10 and 21 weeks of age. Individual growth rates and group feed intake and feed conversion ratios were calculated for the growing period (4 to 10 weeks of age) and the finishing period (10 to 21 weeks of age). Carcasses were weighed at the abattoir, and backfat measurements were taken at the $P_2$ position using an Ulster probe. Within-group range in body weight and carcass parameters was calculated by subtracting the value for the lightest pig in the group from that for the heaviest pig.

The behaviour of each group of pigs was observed five times per day over the two-day period immediately after pigs moved to finishing accommodation. During each observation, the frequency of occurrence of aggressive behaviours, such as fighting, biting, headthrusting, chasing and displacing from the feeder or drinkers, was recorded for a 1 minute period. The total frequency of aggressive behaviours during the first two days of the finishing period was calculated.

## Results and discussion

### Effect of regrouping strategy at 4 weeks of age

Within-group range in body weight remained lower in uniform than in mixed weight groups at 10 weeks of age ($P<0.01$) (Table 1). However, by the time the pigs reached slaughter weight (at 21 weeks of age), there were no significant differences in within-group range in weight between uniform and mixed weight groups. Production performance during the growing and finishing periods did not differ significantly between uniform and mixed weight groups ($P>0.05$) (Table 1).

**Table 1** Mean range in body weight and carcass parameters, and production performance in groups formed at 4 weeks of age

| | Uniform | Mixed weight | SEM | P |
|---|---|---|---|---|
| **Within-group range** | | | | |
| 4 week weight (kg) | 2.03 | 4.58 | 0.111 | <0.001 |
| 10 week weight (kg) | 12.13 | 14.19 | 0.674 | <0.01 |
| 21 week weight (kg) | 35.29 | 33.38 | 2.440 | NS |
| Carcass weight (kg) | 23.42 | 23.14 | 1.651 | NS |
| Backfat (mm) | 6.95 | 7.62 | 0.639 | NS |
| **Mean production performance** | | | | |
| *Growing period (4-10 weeks)* | | | | |
| Feed intake (g/day) | 758.2 | 757.8 | 8.39 | NS |
| Growth rate (g/day) | 507.5 | 511.4 | 5.53 | NS |
| Feed conversion ratio | 1.49 | 1.48 | 0.012 | NS |
| *Finishing period* | | | | |
| Feed intake (kg/day) | 2.15 | 2.15 | 0.045 | NS |
| Growth rate (g/day) | 825.8 | 832.1 | 10.74 | NS |
| Feed conversion ratio | 2.60 | 2.58 | 0.046 | NS |
| 21 week weight (kg) | 98.31 | 99.34 | 0.936 | NS |
| Carcass weight (kg) | 73.63 | 74.69 | 0.735 | NS |
| $P_2$ backfat (mm) | 11.43 | 11.50 | 0.252 | NS |

These results show that there are no benefits in forming uniform weight groups at weaning in terms of reducing within-group range in weight at slaughter. Previous research suggested that there may be particular benefits for small pigs of being housed separately from large pigs during the growing period, in terms of gaining adequate access to feed (O'Connell *et al.*, 2004). However in the current study, growth rates during the growing period of small pigs within uniform weight groups and within mixed weight groups were identical (growth rate of 471 g/day for small pigs in both group types).

Although within-group range in weight remained higher in mixed weight than in uniform weight groups at 10 weeks of age, the range in weight within uniform groups increased substantially during the growing period. In general, growth rate appeared more variable during this period than in the finishing period. For example, within-group range in weight in uniform groups increased by a factor of 6 during the growing period, but only by a factor of 3 during the finishing period. It is likely that increased variation in growth during the post weaning period reflected differing abilities of pigs to cope with the weaning process.

**Effect of regrouping strategy at 10 weeks of age**

Forming uniform weight groups at 10 weeks of age led to reductions in within-group range in slaughter weight ($P<0.01$) and carcass weight ($P<0.1$), and did not significantly affect production performance (Table 2). Mean levels of aggressive behaviour during the post mixing period did not differ significantly between uniform and mixed weight groups ($P>0.05$).

**Table 2** Mean range in body weight and carcass parameters, and production performance in groups formed at 10 weeks of age

| | Uniform | Mixed weight | SEM | P |
|---|---|---|---|---|
| **Within-group range** | | | | |
| 10 week weight (kg) | 6.86 | 13.54 | 1.188 | <0.001 |
| 21 week weight (kg) | 26.35 | 33.62 | 3.093 | <0.01 |
| Carcass weight (kg) | 18.61 | 21.50 | 2.093 | <0.1 |
| Backfat (mm) | 7.24 | 7.00 | 0.810 | NS |
| **Mean production performance** | | | | |
| Feed intake (kg/day) | 2.13 | 2.15 | 0.057 | NS |
| Growth rate (g/day) | 821.1 | 818.9 | 13.61 | NS |
| Feed conversion ratio | 2.60 | 2.63 | 0.059 | NS |
| 21 week weight (kg) | 97.67 | 97.27 | 1.186 | NS |
| Carcass weight (kg) | 74.01 | 73.25 | 0.931 | NS |
| $P_2$ backfat (mm) | 11.32 | 11.51 | 0.319 | NS |

These results show that within-group range in slaughter weight can be reduced by 7 kg through forming uniform weight groups at the start of the finishing period. Walker, (2002) suggested that observed differences in slaughter weight of pigs did not always translate into differences in carcass weight. However, in the present study, within-group range in carcass weight was 3 kg lower when uniform groups were formed at 10 weeks of age than when mixed weight groups were formed at this age, or when groups were formed at weaning at 4 weeks of age (see Table 1). Therefore, in production systems which operate a 'group in/group out' regime in finishing accommodation, forming uniform weight groups at the start of the finishing period will result in less variation in carcass weight.

In production systems which operate on the basis that pigs are sent for slaughter as soon as they reach a target slaughter weight, then forming uniform weight groups at the start of the finishing period will lead to more efficient use of finishing accommodation. This is due to the fact that the time taken for all pigs in the group to reach a target slaughter weight is reduced by 1 week if uniform weight groups are formed at 10 weeks of age. This is based on the assumption that growth rate of pigs at this age is approximately 995g/day (Weatherup *et al.*, 1998). Therefore, in mixed weight groups it will take approximately 5 weeks for all pigs to reach target slaughter weight (due to within-group weight range of 33.6 kg), whereas in uniform weight groups it will take approximately 4 weeks for all pigs to reach slaughter weight (due to within-group weight range of 26.4 kg).

Uniform groups of small, medium and large pigs formed at 10 weeks of age weighed 90, 99 and 104 kg at 21 weeks of age, and had carcass weights of 68, 75 and 79 kg, respectively. If target slaughter weight is 99 kg (for target carcass weight of 75 kg), then groups of large pigs would be slaughtered at 20 weeks, medium pigs at 21 weeks and small pigs at 22 weeks of age. Mixed weight groups, or groups formed at weaning, would be slaughtered at 21 weeks of age. These results suggest that large groups will reach slaughter weight 2 weeks earlier, and medium weight groups 1 week earlier, than mixed weight groups. Groups of small pigs should all reach slaughter weight at the same time as groups of mixed weight pigs. These results are presented in Table 3. They suggest that forming uniform weight groups at 10 weeks of age will result in three additional pen weeks in finishing accommodation.

**Table 3** Effect of forming uniform weight groups (small, medium, large) at 10 weeks of age on use of finishing accommodation

| | **Mean slaughter age** | **Pen clearing time** | **Additional pen weeks** |
|---|---|---|---|
| Mixed weight (control) | 21 weeks | 5 weeks | 0 |
| Small | 22 weeks | 4 weeks | 0 |
| Medium | 21 weeks | 4 weeks | +1 week |
| Large | 20 weeks | 4 weeks | +2 weeks |

### Effect of regrouping at 10 weeks of age on aggression and performance

A major concern associated with regrouping pigs at the start of the finishing period is the effect that it may have on levels of aggression, and on subsequent performance during the finishing period. In the current study regrouped pigs showed significantly more aggressive interactions during the two day post mixing period than non-regrouped pigs (regrouped: 0.95; non-regrouped: 0.45; SEM 0.15/min; $P<0.05$). However, growth rate, feed intake and feed conversion ratio during the finishing period did not differ significantly between regrouped and non-regrouped pigs ($P>0.05$).

The increased aggression shown among regrouped pigs concurs with previous research (Francis *et al.*, 1996), and reflects the establishment of social relationships. These effects appear to be transient, and do not have a long-term effect on performance. However, acute stress associated with aggression can suppress the immune system, thereby making pigs more susceptible to disease (Hessing and Tielen, 1994).

## Conclusions

- Forming uniform weight groups at the start of the finishing period makes more efficient use of finishing accommodation
- However, regrouping finishing pigs leads to acute aggression which has negative welfare implications
- Future research should concentrate on reducing variability in growth during the growing period, so that formation of uniform weight groups at weaning leads to reduced within-group variation in slaughter weight

# Study 2 - Strategies for regrouping sows in large dynamic groups

## Introduction

Housing dry sows in large rather than small groups makes more efficient use of sow housing. Large groups are often operated as dynamic groups, whereby sows which are due to farrow are continually being replaced by those that have just been mated. There are problems associated with these systems, however, in terms of newly-introduced sows being subjected to high levels of aggression from 'resident'sows. This aggression not only affects welfare, but may also adversely affect reproductive performance (Mendl *et al.*, 1992). Previous research suggested that these problems may be exacerbated if more than 10% of the group is replaced at a time (Bokma, 1990). However, general on-farm observations suggest that aggression is reduced if higher replacement rates are used. As typical batch farrowing systems require 20-25% replacement rates, it is important to clarify this issue.

The aim of the present study was to assess the effect of replacing 10, 20, 30 or 40% of a group of forty sows on the welfare of newly-introduced sows to the group.

## Method

### Treatments

The effect of replacement rate on the welfare of newly-introduced sows to a dynamic group was assessed using four treatments and five replicates. Treatments were applied at 3 week intervals and are described as follows:

1. One group of four sows added to a dynamic group of 40 sows
2. Two groups of four sows added to a dynamic group of 40 sows
3. Three groups of four sows added to a dynamic group of 40 sows
4. Four groups of four sows added to a dynamic group of 40 sows

Three days prior to the sows being added to the group, the same number of animals were removed from the group. Treatments 1 to 4 were equivalent to replacement rates of 10, 20, 30 and 40% of the group, respectively.

### Animals, management and housing

Two hundred Large White x Landrace multiparous sows were used in this experiment. Piglets were weaned from the sows when they were 24 ± 2 days of age and the sows were weighed and mixed into groups of four animals which were housed in service pens (day 1). Sows were artificially inseminated on day 5, and transferred as a group into the dynamic group on day 33.

In each replicate either one, two, three or four groups of four sows were added to the dynamic group at 3 week intervals. Sows remained in the dynamic group for a period of 11 weeks.

In the dynamic group the sows were housed in a split-yard system (18.2 x 7.8 m) with three kennels in yard 1 and three kennels in yard 2. Both yards contained a slatted exercise and drinking area (Figure 1). Yard 1 was separated from yard 2 by gates and an electronic feed station which allowed individual feeding of sows. The entrance to the feed station was in yard 1 and the exit was in yard 2. Once a sow entered the feed station she was prevented from returning to yard 1 or from re-entering the feed station until the following morning. Each sow was fed a 2.5 kg concentrate ration over a 13 minute period, after which the exit gate opened automatically to allow the sow to leave the feeder and simultaneously an entry gate opened to allow the next sow to enter the feeder. The feed cycle started at approximately 0800 hours when all sows were moved from yard 2 to yard 1.

At 1500 hours each day extra kennel space was provided for the sows in the post-feeding yard by allowing them access to a fourth kennel area which had previously been used by sows in the pre-feeding yard. This was achieved by closing the gate into this kennel in the pre-feeding yard and opening the gate into this kennel in the post-feeding yard.

## Parameters measured

### Behaviour

The dynamic group of sows was recorded continuously in real time by video cameras during the first 7 days after new sows were added into it. From these recordings, observations were made of aggressive behaviour directed towards newly-introduced sows on the first day post mixing, and of location and behavioural states of the newly-introduced sows during the 7 day post mixing period.

### Injury level

Injuries were recorded from newly introduced sows one week after they were mixed into the dynamic group. Injuries were measured on 11 separate areas of the body including the head, right ear, left ear, right shoulder, left shoulder, back, right flank, left flank, right hindquarter, left hindquarter and vulva.

They were recorded on a scale of 0 to 3 which was defined as follows: 0 = no injuries, 1 = one to three injuries; 2 = four to six injuries; 3 = more than six injuries.

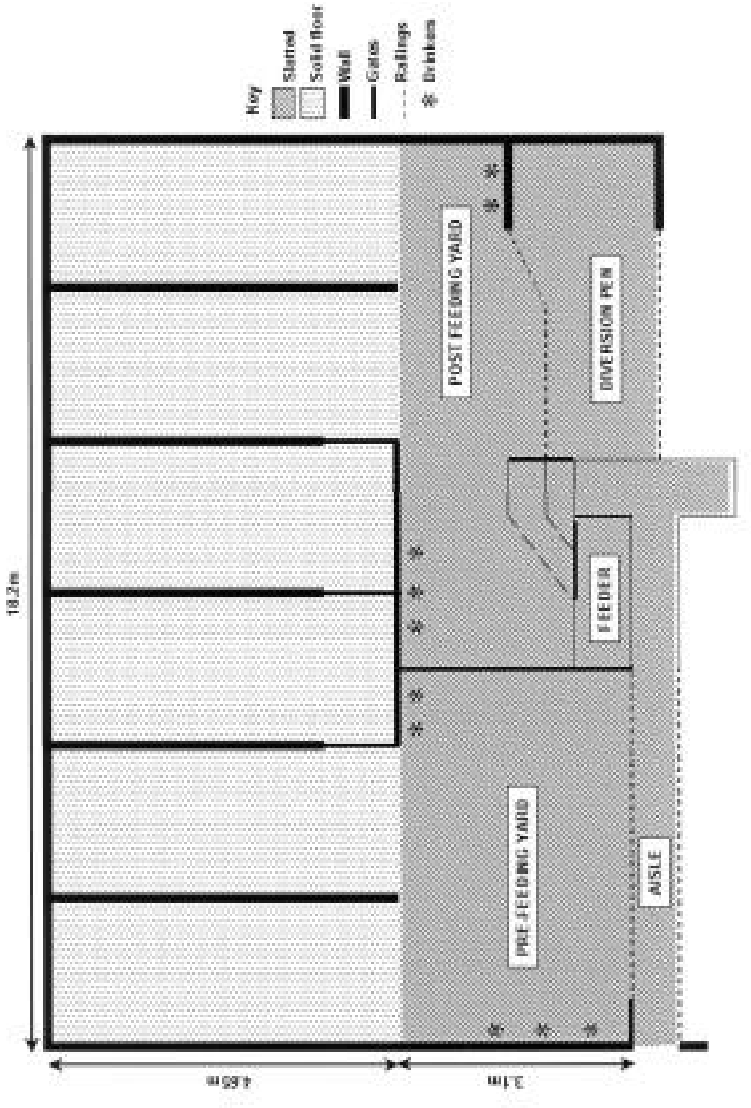


**Figure 1** Layout of split-yard system for dynamic group

## Results and discussion

### Lying behaviour

In general, differences were shown between newly-introduced sows in the 10% replacement rate treatment and sows in the higher replacement rate treatments. Newly-introduced sows in the 10% replacement rate treatment spent more time in slatted areas and less time in kennel areas than newly-introduced sows in all other treatments (P<0.05) (Figure 2).

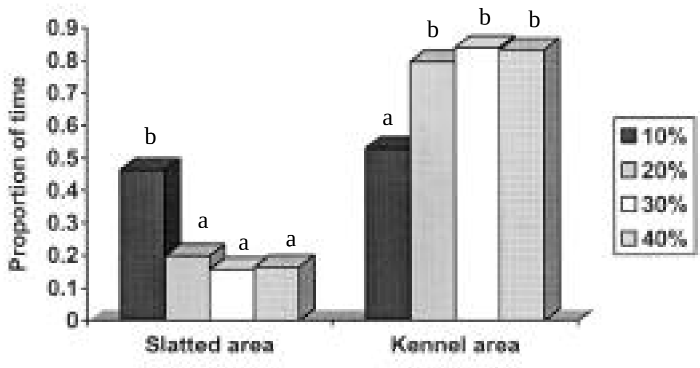


**Figure 2** Influence of replacement rate on time spent in kennel or slatted areas by newly-introduced sows during the first week in a dynamic group

Kennel areas are viewed as prime resting areas because of reduced disturbance by active animals (Spoolder, 1998), and also presumably because of increased warmth and comfort. Therefore the fact that newly introduced sows with the 10% replacement rate treatment spent less time resting in kennel areas than newly-introduced sows in other treatments suggests that their welfare was compromised. In addition, increased time spent lying in slatted areas could lead to increased incidences of vulval infection if slats are unclean (D. Stewart, personal communication).

When newly-introduced sows entered kennel areas, those in the 10% replacement rate treatment spent approximately twice as much time standing, and less time lying down, than newly-introduced sows in all other treatments (Figure 3). In addition to reflecting reduced time spent resting and thus poorer welfare (Beattie *et al.*, 1995), this increased activity within kennel areas by newly-introduced sows in the 10% replacement rate treatment is likely to have created increased disturbance and aggression among resident sows (Durrell, 2002).

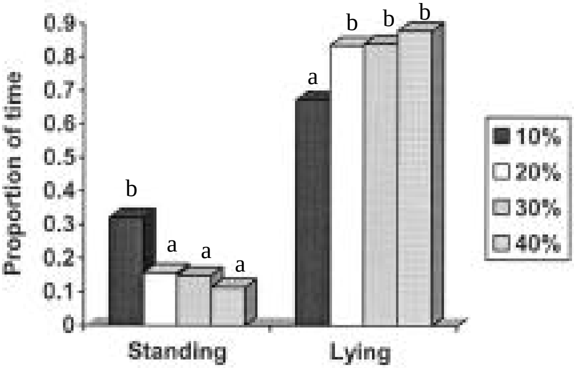


**Figure 3** Influence of replacement rate on time spent standing or lying within kennel areas by newly-introduced sows during the first week in a dynamic group

Finally, when newly-introduced sows in the 10% replacement rate treatment lay down within kennel areas, they remained socially isolated from other sows. This was reflected in reduced time spent lying in contact with other sows and increased time lying close to the wall, compared with newly-introduced sows in other treatments (P<0.05) (Figure 4). This type of behaviour suggests greater levels of 'social unrest' among sows in the 10% replacement rate treatment as opposed to those in higher replacement rate treatments (Olsson and Samuelsson, 1993). No differences were shown in the lying behaviour of newly-introduced sows in the 20, 30 and 40% replacement rate treatments.

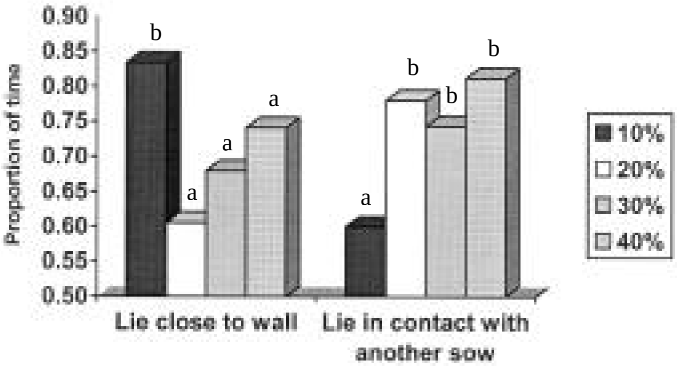


**Figure 4** Influence of replacement rate on lying behaviour within kennels of newly-introduced sows during the first week in a dynamic group

It is likely that differences in use of kennels and in lying behaviour between newly-introduced sows in the 10% replacement rate treatment and those in other treatments were due to the greater number of resident sows to which they were exposed. In the present study, all sows spent the majority of their time in the post-feeding yard, where they had access to four kennel areas between approximately 1500 hours and 0800 hours the next day. When 10% replacement rates were used, resident sows were the predominant occupants of all these kennel areas, and this may have deterred newly-introduced animals from resting in them, or from lying in contact with other animals when they did.

When replacement rates were increased to 20% or more of the dynamic group, it was possible for newly-introduced sows to predominate within a particular kennel area. This, in turn, may have led to greater use of kennel areas and greater time spent lying in contact with other animals when they were within kennel areas.

These results suggest that replacing 10% or less of a dynamic group compromises the welfare of newly-introduced animals. There does not appear to be any additional welfare benefit associated with increasing replacement rates above 20% of the group. The ability of newly-introduced sows to dominate within a particular kennel area appears to be a key factor in determining their use of kennel areas, and thus in promoting health and welfare.

## Aggression and injuries

Newly-introduced sows in different replacement rate treatments suffered similar levels of aggressive behaviour when mixed into the dynamic group (10%: 0.018, 20%: 0.013, 30%: 0.011, 40%: 0.029, SEM 0.0067/min). They also showed similar injury scores at 1 week post mixing (10%: 10.75, 20%: 8.23, 30%: 8.92, 40%: 8.69, SEM 1.456). As replacement rate increased, the number of resident sows to which newly introduced animals were exposed decreased. It was anticipated that this would lead to a reduction in levels of aggression directed towards newly introduced sows. However, as replacement rates increased, the number of unfamiliar animals being added to the group also increased, and these animals began to fight amongst themselves.

Average levels of injury sustained by newly-introduced sows to the dynamic group were approximately twice as high as those sustained when sows are mixed into small static groups (O’Connell *et al.*, 2002). This provides further evidence that dynamic grouping systems can cause significant welfare problems for newly-introduced animals. Results of the current trial show that these problems are not alleviated by manipulating replacement rate. Future research should concentrate on investigating environmental or nutritional strategies to reduce aggression in large dynamic groups.

## Conclusions

- Replacing 10% or less of a dynamic group of 40 sows compromises the welfare of newly-introduced animals.
- Replacement rate can be varied between 20 and 40% without affecting the welfare of newly-introduced animals.
- The ability of newly-introduced sows to dominate within a particular kennel area is important in terms of determining their use of that area.

## Acknowledgements

The authors gratefully acknowledge funding for this research from the Pig Production Development Committee in conjunction with the Ulster Farmer's Union Pigs Committee, and from the Department of Agriculture and Rural Development for Northern Ireland. We also wish to thank the staff of the pig unit of the Agricultural Research Institute of Northern Ireland for excellent technical assistance and care of the animals.

## References

ANDERSEN I.L., ANDENÆS H., BØE K.E., JENSEN P. and BAKKEN M. (2000) The effects of weight asymmetry and resource distribution on aggression in groups of unacquainted pigs. Applied *Animal Behaviour Science*, **68**: 107-120.

BEATTIE V.E., WALKER N. and SNEDDON I.A. (1995) Effects of environmental enrichment on behaviour and productivity of growing pigs. *Animal Welfare*, **4**: 207-220.

BOKMA S. (1990) Housing and management in practise - partly slatted systems. Proceedings of an International Symposium, Electronic Identification in Pig Production. Royal Agricultural Society of England, Stoneleigh, pp 37-46.

DURRELLJ.L. (2000) *Improving the welfare of group housed sows*. Ph.D. Thesis, Queens University Belfast.

HESSING M.J.C. and TIELEN M.J.M. (1994) The effect of climatic environment and relocating and mixing on health status and productivity of pigs. *Animal Production*, **59**: 131-139.

MENDLM., ZANELLAA.J. and BROOM D.M. (1992) Physiological and reproductive correlates of behavioural strategies in female domestic pigs. *Animal Behaviour*, **44**: 1107-1121.

O'CONNELL N.E. and BEATTIE V.E. (1999) Influence of environmental enrichment on aggressive behaviour and dominance relationships in growing pigs. *Animal Welfare*, **8**: 269-279.

O'CONNELL N.E., BEATTIE V.E. and MOSS B.W. (2003) Influence of social status on the welfare of sows in static and dynamic groups. *Animal Welfare*, **12**: 239-249.

O'CONNELL N.E., BEATTIE V.E. and WEATHERUP R.N. (2004) Influence of group size during the post-weaning period on the performance and behaviour of pigs. *Livestock Production Science*, **86**: 225-232.

OLSSON A.-Ch. and SAMUELSSON O.V. (1993) Grouping studies of lactating and newly weaned sows. In: E. Collins and C. Boon (Eds), Livestock Environment IV, Fourth International Symposium, American Society of Agricultural Engineers, pp 475-482.

SPOOLDER H.A.M. (1998) *Effects of food motivation on stereotypies and aggression in group housed sows*. Ph.D. Thesis, Wageningen Agricultural University, The Netherlands.

STOOKEY, J.M. and GONYOU, H.W. (1994) The effects of regrouping on behavioural and production parameters in finishing swine. *Journal of Animal Science*, **72**: 2804-2811.

WALKER N. (2002) Carcass quality of Northern Ireland pigs compared with those originating in the Republic of Ireland and Great Britain. Report prepared for the Department of Agriculture and Rural Development for Northern Ireland, February 2002.

WEATHERUPR.N., BEATTIE V.E., MOSS B.W., KILPATRICK D.J. and WALKER N. (1998) The effect of increasing slaughter weight on the production performance and meat quality of finishing pigs. *Animal Science*, **67**: 591-600.

# INVESTIGATIONS INTO PHOSPHORUS REQUIREMENTS OF GROWING/ FINISHING PIGS AND THE USE OF PHYTASE

**M. Elizabeth E. McCann, Kelvin J. McCracken,**
**Violet E. Beattie, Elizabeth Magowan, Sam Smyth,**
**Raymond Bradford and Wallace Henry**

## Study 1. Phosphorus requirements

### Introduction

The efficient and economic production of pig meat depends on the use of good management and appropriate genetics and nutrition. Feed accounts for up to 70% of the costs of pig production. There is, therefore, an economic imperative to ensure that the feed is appropriate to achieve fast and efficient growth. There is also a moral and economic imperative to ensure that the welfare needs of animals are met. Recently, environmental concerns, such as pollution of the atmosphere and waterways, have become important social and political issues. In relation to production and welfare, the feed needs to supply a wide range of nutrients in the correct proportions. Environmental issues relating to agriculture are mainly associated with pollution arising from the inevitable excretion of nitrogen- and phosphorus-containing substances. Whilst the excretion of phosphorus (P) associated with pig production is less than 10% of agricultural P output to the environment (Foy *et al.*, 2002) and only about 6% of the total Poutput in Northern Ireland, it has come in for careful scrutiny, partly because the slurry tends to be spread onto a relatively small part of the land mass with possible consequences for pollution of waterways.

### Importance of P for maintenance and growth

Phosphorus is second only to calcium in terms of its quantitative requirements. It is closely involved with calcium in the formation of bone. Phosphorus also plays a central role in metabolism as an important component of phospholipid, which is essential for the integrity and function of cell membranes, and in some key enzymes.

Digestion and absorption of phosphorus depends on the nature of the dietary P, the level and sources of calcium, the buffering capacity of the diet and the presence of adequate levels of vitamin D. Any P which is not digested and absorbed in the small intestine is excreted in the faeces. This tends to be relatively insoluble and is therefore less serious in terms of pollution potential. There is an inevitable excretion of phosphorus in urine arising from turnover in the body (the endogenous losses). In addition any P absorbed in excess of the requirements for growth will be excreted in the urine in a soluble form, which is readily leached into waterways when spread on land, particularly in conditions of high rainfall.

## Assessing the requirements for phosphorus

Quantitatively the main requirement for P is for bone growth which, in turn, is closely related to muscle development and hence liveweight gain. However, it is difficult to predict requirements from growth experiments because (a) the liveweight gain response curve is very flat, (b) growth rate is not a good indicator of bone strength, which is important in terms of welfare and also, in particular, for longevity of breeding stock. It is much more difficult to measure bone strength than growth rate and unfortunately blood parameters such as plasma phosphorus, calcium or alkaline phosphatase are not particularly sensitive to phosphorus deficiency.

It is also important to note that estimates of requirement are based on the population mean. In order to cater for individual variability in requirements it is necessary to allow some margin of safety factor (normally 5 to 10%) to ensure that the needs of the whole population are adequately provided in commercial practice.

## Formulating diets to meet requirements

It is important to recognise that the animal has an absolute daily requirement for digested phosphorus which increases with age/weight. There are four problem areas in converting this into a diet formulation. The greatest is undoubtedly the problem of converting digested P to total P (or vice versa). There is wide variability in digestibility of P from different sources (ranging from as low as 20% for some cereal and vegetable sources up to over 80% for inorganic sources). Furthermore, even though there is a considerable volume of digestibility data in the literature, there are wide discrepancies in reported values. This is illustrated in Table 1, which shows values currently used in different feed formulation matrices.

**Table 1** Estimates of digestible P content (g/kg) of a range of feed ingredients in four different formulation databases (A-D)

| | A | B | C | D |
|---|---|---|---|---|
| Barley | 1.2 | 1.2 | 1.2 | 1.3 |
| Wheat | 1.3 | 1.2 | 1.1 | 1.4 |
| Hipro soya | 1.1 | 1.0 | 2.5 | 1.6 |
| Maize germ | 2.6 | 1.5 | 0.9 | 1.0 |
| Pollard | 3.7 | 2.5 | 3.0 | 2.6 |

Two related problems are the need to take account of the energy value of the diet, since this is likely to affect the amount of feed consumed and the even greater problem of variability in feed intakes between pigs within a group and between herds due to differences in genetics or management, since the normal way to express requirements in practice is as a proportion of the feed.

The final area of difficulty is the application of the relevant legislation affecting the production and sale of feed. In the case of phosphorus the declaration of Pcontent is currently optional for all except fish feed and therefore it is unlikely to be declared. In any case the margins for error are 0.45% in case of excess and 0.15% in case of deficiency. Thus, for a feed with a stated total phosphorus of 0.6%, the legally acceptable range is 0.45 to 1.05%.

## Estimates of requirements for total and digestible P

Table 2 shows the estimated total P requirements for different weight ranges of pigs from four different sources. The increased estimates of requirement from UK sources (ARC) between 1967 and 1988 are readily explained by the increased growth rates coupled with reduced feed intake over that period due mainly to genetic selection. They may also reflect some increasing concerns about welfare. The much lower values quoted by NRC (1998) for USA can be attributed to higher feed intakes associated with differences in breeding and the use of castrates as opposed to boars in that country. Thus the UK estimates are regarded as relevant to the Northern Ireland situation.

**Table 2** Predicted total P requirements (% diet as fed) from different sources

| | ARC (1967) | ARC (1981) | Stranks (1988) | NRC (1998) |
|---|---|---|---|---|
| Birth - 20 kg | 0.65 | 0.78 | 0.82 | - |
| 20 - 50 kg | 0.55 | 0.62 | 0.65 | 0.50 |
| 50 - 100 kg | 0.46 | 0.57 | 0.59 | 0.42 |

The most recent estimates for digestible phosphorus requirements come from a report issued by the British Society of Animal Science (BSAS) (2003) and are summarised in Table 3. These relate to ‘intermediate’ pigs consuming a ‘guideline’ feed intake. The conversion of these figures to total P requirements depends on the digestibility of the dietary sources used. In reality the ‘guideline’ feed intake appears to be about 10% above the norm of *ad libitum*, group-fed pigs in Northern Ireland. This is explicable in terms of different emphases in selection over the past 20 years with consequent lower appetites of the breed lines in Northern Ireland. The BSAS report takes account of such differences with the statement: “Higher levels of dietary macro minerals will be required, *pro rata*, with: diets of higher energy and amino acid density; pigs of high productivity; pigs of diminished appetite”.

**Table 3** Recent estimates (% diet as fed) of digestible P requirements (BSAS, 2003)

| | 10 - 30 kg | 30 - 60 kg | 60 - 90 kg | 90 - 120 kg |
|---|---|---|---|---|
| Digestible P % | 0.34 | 0.25 | 0.24 | 0.22 |

## Studies at ARINI to determine requirements

A major study involving the Agricultural Research Institute of Northern Ireland (ARINI), Agriculture, Food and Environmental Science Division (Newforge Lane), Devenish Nutrition Ltd. and John Thompson and Sons Ltd. was conducted in two parts (a) to determine the response of growing pigs (16-45 kg) to dietary phosphorus, (b) to examine the effects of early Pnutrition through to slaughter. In the grower phase the diets were formulated to contain 0.45, 0.5 and 0.6% total P, the higher levels being obtained by adding monodicalcium phosphate. On analysis they contained 0.50, 0.53 and 0.61% total P. The results (Table 4) show the marked increase in digestibility associated with the inclusion of inorganic P. Of particular interest is that the P digestibility coefficient for the lowest P diet was around 0.5, which was considerably higher than expected from the formulation databases. The urinary P and P retention results suggest that, on one hand, the lowest level of P was marginally deficient whilst the highest level of P resulted in excess P excretion in urine. If one takes the middle diet as being close to optimum this gives a digestible P requirement of 0.29%, which is in line with the mean of the BSAS (2003) estimates for 10-30 and 30-60 kg. In the fattening phase the mean digestibility of P in the diet was 0.48 which was also higher than predicted values. Problems were encountered in formulating diets to the lower levels intended (0.40 and 0.45% P). Thus digestible P values were somewhat above BSAS (2003) estimates. Despite this, the lowest dietary P combination (nominally 0.45% in grower and 0.40% in finisher) gave rise to some reductions in bone strength indicators in the 4th metatarsal bone (Table 5) suggesting some carry-over effects from the marginal deficiency in the grower stage.

**Table 4** Digestibility and excretion of P in diets fed to growing pigs

| **Diet % P** | **0.45** | **0.50** | **0.60** | **SEM** | **P** |
|---|---|---|---|---|---|
| Digestibility coefficient | 0.51 | 0.55 | 0.65 | 0.002 | <0.001 |
| P retained (g/d) | 3.0 | 3.9 | 3.9 | 0.34 | NS |
| Faecal P (g/d) | 3.7 | 3.9 | 3.2 | 0.29 | NS |
| Urinary P (g/d) | 0.7 | 0.9 | 1.9 | 0.17 | <0.05 |

**Table 5** Effects of dietary P on bone parameters

| **Diet P %** | **0.6%** | **0.45 0.40%** | **SEM** | **P** |
|---|---|---|---|---|
| 4th metatarsal bone area ($cm^2$) | 0.94 | 0.92 | 0.010 | <0.05 |
| 4th metatarsal wall thickness (cm) | 1.65 | 1.56 | 0.043 | <0.05 |

## Conclusions

- Phosphorus is an important dietary ingredient for growth and metabolism and it is important to ensure an adequate supply on health and welfare grounds.
- The recent BSAS (2003) estimates for requirement of digestible P appear to be sound in relation to the “guideline” intake used but this is probably about 10% above average Northern Ireland intakes and this aspect should be taken into account in estimating requirements.
- Digestibility of Pin normal commercial diets is higher than most literature values suggest. There is therefore a need to further examine the values used in formulation databases.
- The results have demonstrated that Prequirements are somewhat lower than the levels commonly used in commercial practice and there is therefore scope for a reduction in total Plevels in diets.

A reduction of 0.1% in total phosphorus in diets could give up to a 15% reduction in Pexcretion and even greater reduction in soluble Pexcretion. This is of considerable importance in situations of limited land mass for slurry disposal.

- The relatively small contribution of pigs to the P output excess means that, even if the input of feed P for pigs could be perfectly regulated, the effect on the Northern Ireland total P excess output would be a reduction of only about 1.5%. However, in individual farm situations of high soil P status and proximity to waterways reductions in Pexcretion can be of major importance.

## Study 2.The use of phytase

### Introduction

The majority (60-80%) of phosphorus (P) present in cereal grains is in the form of phytates which are salts of phytic acid (Kornegay, 2001). Pigs do not possess the enzyme phytase which is necessary to hydrolyse P from the phytate molecule. Therefore the P in cereal grain is not very digestible and cereals cannot supply the required level of P. Traditionally, this problem has been overcome by the addition of inorganic P to diets for pigs. This practice has two problems; 1) inorganic P is an expensive component and therefore inclusion in diets increases the cost of production and 2) as the P in cereal grains is not efficiently utilised and inorganic P may be added in excess of requirements, the amount of P excreted is significant. This is an environmental concern as well as contributing to the cost of diet production. In recent years, supplementation of pig diets with the enzyme phytase has been investigated as a means of improving the availability of cereal phytate, thus reducing the requirement for inorganic Pand the amount of Pexcreted. The purpose of this paper is to discuss the extent to which phytase addition to pig diets can achieve improved cereal P availability and reduce the level P excreted within Northern Ireland.

### Phosphorus Sources

In order to discuss the use of phytase in pig diets it is first necessary to consider the sources of P available to the pig. As outlined above, P is supplied in both the inorganic and organic forms. Inorganic P occurs widely in nature and is obtained by mining. The mined crude P is unavailable to the animal and must undergo a chemical reaction to yield phosphoric acid. The phosphoric acid then reacts with sodium or calcium hydroxide to give mono, di or tri sodium or calcium phosphate. Monodicalcium is a mixture of mono and dicalcium sources. As a result of the manufacturing processes these products may vary in; the ratio of Ca:P, physical composition, the level of impurities and in the actual availability of P to the animal. Generally, the mono sources of P have higher availabilities than di or tri sources although all are reported to be relatively highly digestible (>70%) (Whittemore, 1993).

The majority of organic P is supplied in the form of phytate which is present in cereal grains and vegetable protein sources. The phytate molecule cannot be broken down by the pig and therefore the P present has a low digestibility value (<40%) (Whittemore, 1993). Even though phytate has a low digestibility, diets containing high levels of cereal by-products can supply finishing pigs with the required amount of P without the need for additional inorganic P. However, phytate can cause a reduction in the digestibility of other nutrients as a result of it's high chelating potential. Phytate has been reported to chelate or bind with calcium, P, zinc, copper, cobalt, manganese, iron and magnesium, rendering these minerals less available for intestinal absorption (Kornegay, 2001). It has also been reported that phytate binds with amino acids and inhibits proteolytic enzymes under gastrointestinal conditions (Knukles *et al.*, 1985). There is some evidence to suggest that phytate may reduce the energy content of the diet, as Thompson and Yoon, (1984) reported that phytate formed complexes with starch thus reducing availability.

## Use of phytase - what the literature says

Phytase occurs widely in nature i.e. in microorganisms, plants and certain animal tissues. The majority of studies involving phytase have been conducted using phytase derived from the microorganism *Aspergillus* or cereal phytase - although cereal phytase has been less commonly used. Cereals contain varying levels of phytase. For example wheat, barley, oats and soyabean meal contain 1193, 582, 40 and 8 units of activity (U)/kg respectively. Studies from over 50 years ago indicated that cereal phytase was effective in releasing Pfrom the phytate molecule (McCance and Widdowson, 1944; Hill and Tyler, 1954). However, more recent research (Eeckhout and De Paepe, 1991 cited by Kornegay, 2001) has shown that microbial phytase is 74% more efficient than cereal phytase. It has also been reported that dietary processing (i.e. steam pelleting) denatures cereal phytase thus making it ineffective. Therefore, considering the low activity and denaturation by dietary processing, the phytase within cereals (endogenous phytase) is not a reliable source of phytase and if phytase is to have a significant effect it must be supplied in the diet (exogenous supplementation).

As already stated, the majority of studies have been conducted with exogenous supplementation with microbial phytase derived from *Aspergillus*. This type of phytase has two pH optima (2.5 and 5.5) i.e. two points at which pH is optimum to drive hydrolysis of phytate molecules (Kornegay, 2001). As a result, the majority of phytate hydrolysis occurs in the stomach (Jongbloed *et al.*, 1992) although a relatively high level occurs in the large intestine. It is important to target phytate hydrolysis in the stomach as the P released in the large intestine is not readily absorbed and is therefore excreted to the environment in a more available form than if it was still bound in phytate.

Microbial phytase has been reported to be effective in increasing the digestibility of P from phytate. Jongbloed *et al.* (1996) estimated that inclusion of 500 U/kg phytase could replace 0.1% of monocalcium phosphate in the diet. In terms of improving the availability of other nutrients, a number of researchers have reported positive responses. For example, Eeckhout and De Paepe, (1991) cited by Kornegay 2001 observed a significant positive correlation between calcium digestibility and phytase supplementation and suggested a possible explanation - the phytate is hydrolysed in the stomach and is therefore not available to bind to calcium in the small intestine, thus the availability and hence digestibility of calcium increased. These workers suggested that 500 U/kg of phytase could replace between 0.4 and 0.7 g/kg calcium in the diet. Several researchers have examined the effect of phytase on zinc and magnesium digestibility and absorption and have reported improvements (e.g. Nasi and Helander, 1994). However, the amount of these nutrients which phytase can replace in the diet has not yet been established. Jongbloed *et al.*, (1996) measured overall digestibility of crude protein (CP) for diets with or without phytase supplementation and concluded that phytase was effective in improving digestibility of CP. There is less evidence to suggest that phytase may improve the energy level of the diet although some work has been carried out on pigs (Thompson and Yoon, 1984) and poultry (Ravindran *et al.*, 1999) indicating that phytase may improve digestion of starch. It is possible that this is achieved through the hydrolysis of phytate as phytate may bind the α-amylase itself or the calcium ions needed for α-amylase activity or form complexes with starch directly.

## Use of phytase - studies at ARINI

In order to establish the effect of phytase addition on P digestibility and excretion, three studies involving the use of phytase were undertaken at the Agricultural Research Institute of Northern Ireland (ARINI) in conjugation with John Thompson and Sons Ltd and Devenish Nutrition Ltd. The first study examined the effect of dietary P level with and without phytase supplementation, on performance of growing and finishing pigs and nutrient digestibility. Only the effect of phytase supplementation will be discussed in this paper. Diets for growing and finishing pigs were formulated to contain 0.45, 0.5 and 0.6% total P and 0.4, 0.5 and 0.6% total P respectively. The target 0.45, 0.5 (growing), 0.4 and 0.5% (finishing) diets were offered to pigs with and without phytase supplementation. The target 0.6% diet was the control. Addition of phytase had no significant effect on the performance of either growing or finishing pigs. In terms of digestibility and mineral balance, phytase addition improved P digestibility in growing pigs and reduced the amount of P excreted (Table 1). Phytase addition had no significant effect on nitrogen (N) digestibility and, although N retained was higher with phytase, there was no consistent effect on N excreted. Phytase addition of growing pig diets had no significant effect on the digestibility of calcium, magnesium or dry matter (DM), although calcium digestibility was numerically improved with phytase. The effect of phytase on digestibility and mineral balance in finishing pigs was not consistent with the growing pig data as phytase actually decreased P digestibility (0.46 vs. 0.49).

One of the main conclusions arising from this work was that phytase was effective in increasing P digestibility and reducing P excretion when added to growing pig diets. However, phytase supplementation of finishing pig diets was not effective. A possible explanation for this may be due to the fact that the finishing diets contained a lower level of oil which resulted in less lubrication during pelleting leading to the generation of more heat through increased friction. Therefore phytase may have been inactivated in finishing pig diets.

**Table 1** Digestibility and P and N balance of diets offered to growing pigs

| | **Control** | **Phytase +** | **Phytase -** | **SEM** | **P** |
|---|---|---|---|---|---|
| P digestibility coefficient | $0.66^{b}$ | $0.64^{b}$ | $0.54^{a}$ | 0.002 | <0.001 |
| P retained (g/d) | 4.1 | 3.9 | 3.6 | 0.29 | NS |
| P excreted (g/d) | 5.1 | 4.1 | 4.6 | 0.24 | NS |
| N digestibility coefficient | 0.88 | 0.86 | 0.86 | 0.001 | NS |
| N retained (g/d) | 26.8 | 28.4 | 26.5 | 1.38 | NS |
| N excreted (g/d) | 21.3 | 22.8 | 23.0 | 1.66 | NS |

$^{a,b}$ - Means without a common superscript are significantly different

The aim of the second study, was to establish if dietary processing did indeed inactivate the phytase. Five finishing diets were formulated containing on average 0.44% P and offered to 10 male pigs housed in metabolism crates. The five diets were: meal + and - dry phytase; pellets + and - dry phytase and; pellets + liquid phytase. The liquid enzyme was sprayed onto the diet after pelleting and thus was not subject to heat treatment. The experiment was conducted in a crossover design and consisted of four periods. Each period comprised a 7 day pre-feed and a 7 day faecal and urine collection. Some of the results are presented in Table 2. Pdigestibility was not significantly improved by the addition of dry enzyme to either meal or pelleted diets but a significant increase was observed when liquid enzyme was added to pelleted diets. Phytase had no effect on N, DM, calcium or magnesium digestibility. However, as Table 2 shows, pelleted diets resulted in a higher N and DM digestibility than meal diets.

**Table 2** Digestibility of P, N and DM for meal and pellet diets with and without phytase

| | Meal + | Meal - | Pellet + | Pellet - liquid | Pellet + | SEM | P |
|---|---|---|---|---|---|---|---|
| P digestibility coefficient | 0.44[ab] | 0.39[a] | 0.52[b] | 0.46[ab] | 0.62[c] | 0.003 | <0.001 |
| N digestibility coefficient | 0.83[a] | 0.81[a] | 0.87[b] | 0.87[b] | 0.87[b] | 0.010 | <0.01 |
| DM digestibility coefficient | 0.83[a] | 0.82[a] | 0.86[b] | 0.86[b] | 0.86[b] | 0.007 | <0.01 |

[a,b,c] - Means without a common superscript are significantly different

The main conclusion from this study is that dry enzyme products were not effective in achieving a response in P digestibility. It was suggested that the method of manufacture may have resulted in the enzyme being so effectively protected, to withstand denaturation by dietary processing, that it was unable to hydrolyse phytate.

A third study was designed to examine the effect of a range of phytase products (both liquid and dry) on digestibility and nutrient balance of finishing pig diets. Ten meal finishing diets were formulated: five were supplemented with dry phytase; four with liquid phytase; and the remaining diet was the control (-phytase). Both dry and liquid phytase products were equally effective in increasing P and DM digestibility and P retention and in reducing Pexcretion when compared with the control (Table 3). There was no significant effect of phytase on N digestibility or N balance, nor was there a consistent effect on calcium or magnesium digestibility. DM digestibility was, however, improved with phytase addition.

**Table 3** Digestibility and P balance of diets supplemented with dry or liquid phytase

| | Control | Dry | Liquid | SEM | P |
|---|---|---|---|---|---|
| P digestibility coefficient | 0.46[a] | 0.56[b] | 0.56[b] | 0.002 | <0.001 |
| P retained (g/d) | 3.3[a] | 4.1[b] | 4.1[b] | 0.15 | <0.001 |
| P excreted (g/d) | 4.2[a] | 3.5[a] | 3.5[a] | 0.14 | <0.01 |
| Calcium digestibility coefficient | 0.52[a] | 0.61[b] | 0.59[ab] | 0.003 | <0.01 |
| Magnesium digestibility coefficient | 0.31[a] | 0.35[b] | 0.32[a] | 0.002 | <0.01 |
| Dry matter digestibilitycoefficient | 0.83[a] | 0.84[b] | 0.84[b] | 0.004 | <0.001 |

[a,b] - Means without a common superscript are significantly different

## Use of phytase - conclusions

- Phytase is effective in improving P digestibility in pig diets but responses observed in ARINI studies were less than that observed in the literature, as P digestibility of the control diets were higher than suggested in the literature.
- From a financial perspective, phytase may be more beneficial in a home mixer situation where higher levels of inorganic Pare added to diets. Compounders tend to include by-products, which are high in phytate P, which although not highly available to the pig, can still provide enough P to finishing pigs without the need for inorganic phosphorus.
- Phytase can reduce excretion of P to the environment. However, it must be stressed that phytase should only be added to diets in parallel with a reduction in dietary Pcontent. If phytase is added to a diet, which has a high level of P, the P released from phytate is not required by the pig and is broken down to available P and excreted. In this instance the addition of phytase will increase P excretion. Dietary P levels must be reduced when supplementing with phytase to ensure that this does not occur.
- Blanket inclusion of phytase is not recommended.
- Phytase had no effect on production performance.
- Both dry and liquid enzymes are equally effective in improving P digestibility, when used in unheated diets, but the effect of dietary processing may be detrimental to phytase efficiency.
- No consistent effects were observed in N, calcium or magnesium digestibility values although the numerical differences were generally positive.

## Acknowledgements

This research was jointly funded by John Thompson and Sons Ltd, Devenish Nutrition Ltd and the Department of Agriculture and Rural Development for Northern Ireland. The experimental work was conducted at ARINI and on the farm of Mr Gary Anderson. The authors wish to acknowledge the staff at both sites for their technical assistance and care of the animals.

## References

ARC (1967) The nutrient requirements of farm livestock No 3 Pigs. Technical review. ARC, London.

ARC (1981) The nutrient requirements of pigs. Commonwealth Animal Bureau, Slough, England.

BRITISH SOCIETY OF ANIMAL PRODUCTION (2003) Nutrient requirement standards for pigs. Report of a BSAS Working Party.

FOYR.H., BAILEY J.S. and LENNOX S.D. (2002) Mineral balances for the use of phosphorus and other nutrients by agriculture in Northern Ireland from 1925 to 2000 - methodology, trends and impacts of losses to water. *Irish Journal of Agricultural and Food Research* **41**: 247-263.

HILL R. and TYLER C. (1954) The influence of time, temperature, pH and calcium carbonate on the activity of the phytase of certain cereals. *Journal of Agricultural Science*, **44**: 306-310.

JONGBLOED A.W., KEMME P.A. and MORZ Z. (1996) Effectiveness of Natuphos phytase in improving the bioavailabilites of phosphorus and other nutrients for growing-finishing pigs. In: Coelho M.B. and Kornegay E.T. (eds) *Phytase and Animal Nutrition and Waste Management*. BASF Corporation, New Jersey.

JONGBLOED A.W., MORZ Z. and KEMME P.A. (1992) The effect of supplementary *Aspergillus niger* phytase in diets for pigs on concentration and apparent digestibility of dry matter, total phosphorus and phytic acid in different sections of the alimentary tract. *Journal of Animal Science*, **70**: 1159-1168.

KNUCKLES B.E., KUZMICKY D.D. and BetSchart A.A. (1985) Effect of phytate and partially hydrolysed phytate on *in vitro* protein digestibility. *Journal of Food Science*, **50**: 1080-1082.

KORNEGAY E.T. (2001) Digestion of phosphorus and other nutrients: the role of phytases and factors influencing their activity. In: Bedford M.R. and Partridge G.G. (eds) *Enzymes in Farm Animal Nutrition*. CAB International.

McCANCE R.A. and WIDDOWSON E.M. (1944) Activity of the phytase in different cereals and its resistance to dry heat. *Nature*, **153**: 660.

NASI M. and HELENDER E. (1994) Effects of microbial phytase supplementation and soaking of barley-soyabean meal on availability of plant phosphorus for growing pigs. *Acta Agriculturae Scandinavica*, **44**: 79.

NRC (1998) Nutrient requirements of swine. 10th Revised edition. National Academy Press, Washington, USA.

RAVINDRAN V., CABAHUG S., RAVINDRAN G., SELLE P.H. and BRYDEN W.L. (1999) Influence of microbial phytase on apparent ileal amino acid digestibility of feedstuffs for broilers. *Poultry Science*, **78**: 699-706.

STRANKS M.H., COOKE B.C., FAIRBAIRN C.B., FOWLER N.G., KIRBY P.S., McCRACKEN K.J., MORGAN C.A., PALMER F.G. and PEERS D.G. (1988) Nutrient allowances for growing pigs. *Research and Development in Agriculture*, **5**: 71-88.

THOMPSON L.U. and YOON J.H. (1984) Starch digestibility as affected by polyphenols and phytic acid. *Journal of Food Science,* **49**: 1228-1229.

WHITTEMORE C.T. (1993) *The science and practice of pig production*, CAB International.

# RECENT & CURRENT PIG RESEARCH PROJECTS

| Project Title: | Project funded by: | For further information on project contact: |
|---|---|---|
| **Production** | | |
| Evaluation of sire-types available within N.I. | DARD, UFU and PPDC | Elizabeth McCann |
| Effect of feeder type and change pig performance | DARD, UFU and PPDC | Elizabeth McCann & Elizabeth Magowan |
| The use and accuracy of instruments to measure backfat in pigs | DARD, UFU and PPDC | Elizabeth Magowan |
| Effect of photoperiod on pig performance | DARD, UFU and PPDC | Elizabeth McCann & Elizabeth Magowan |
| Investigation of the variation in growth rate between pig herds within Northern Ireland and factors affecting this variation | DARD, John Thompson & Sons Ltd and Devenish Nutrition Ltd | Elizabeth Magowan & Elizabeth McCann |
| Grouping by gender | DARD, UFU and PPDC | Elizabeth Magowan & Elizabeth McCann |
| Effect of drinker design on pig performance | DARD, UFU and PPDC | Elizabeth Magowan & Elizabeth McCann |
| Effect of different feeding systems on weaned pig performance | DARD, UFU and PPDC | Elizabeth Magowan & Elizabeth McCann |
| **Nutrition** | | |
| Phosphorus requirements and the use of phytase in pig diets | DARD, John Thompson & Sons Ltd and Devenish Nutrition Ltd | Elizabeth McCann |

| | | |
|---|---|---|
| Alternative sources of energy for pigs | DARD, John Thompson & Sons Ltd and Devenish Nutrition Ltd | Elizabeth McCann |
| Factors affecting variability of wheat for growing pigs | DARD, Danisco Animal Nutrition | Elizabeth McCann |
| Effect of the level of wheat inclusion on finishing pig performance and digestibility. | DARD | Elizabeth McCann & Elizabeth Magowan |
| Optimising nutrient use through diet manipulation of finishing pig diets. | DARD, John Thompson & Sons Ltd and Devenish Nutrition Ltd | Elizabeth McCann & Elizabeth Magowan |
| Effect of diet processing on growth performance and digestibility of pigs. | DARD | Elizabeth McCann & Elizabeth Magowan |

## Behaviour & Welfare

| | | |
|---|---|---|
| Management strategies for weaned pigs | DARD, UFU & PPDC | Niamh O'Connell |
| Alternative enriching devices for pigs | DARD | Niamh O'Connell |
| Management of sows in large groups | DARD | Niamh O'Connell |
| Social stress in pigs | DARD | Niamh O'Connell |
| Feed intake behaviour | DARD, UFU and PPDC | Niamh O'Connell |
| Genetic and environmental factors affecting tail biting in pigs | DEFRA | Niamh O'Connell |

NOTES

NOTES

# Agricultural Research Institute of Northern Ireland

**Large Park, Hillsborough, Co. Down, BT26 6DR**

**Telephone: (028) 9268 2484**

**Fax: (028) 9268 9594**

**E-mail: arini@dardni.gov.uk**

**Website: www.arini.ac.uk**


Department of
Agriculture and
Rural Development
www.dardni.gov.uk

AN ROINN
Talmhaíochta agus
Forbartha Tuaithe

MÄNNYSTRIE O
Fairms an
Kintra Fordèrin