# Improve performance with liquid feeding

*by Dr B. P. Gill, Meat and Livestock Commision, PO Box 44, Winterhill House, Snowdon Drive, Milton Keynes MK6 1AX, UK.*

The Finishing Pigs Systems Research Programme, funded by BPEX and Defra, was developed by the Meat and Livestock Commission (MLC) to establish how financial returns could be improved from finishing pigs. Liquid feeding technology was central to this 3.5 year programme, which was based at MLC's Stotfold Pig Development Unit and completed in August 2005.

Within the programme, four large scale trials using over 4,000 pigs housed in either a fully slatted or straw based building, were completed to compare different approaches to liquid feeding (for example, feeding a dry diet in liquid form, phase-feeding, fermenting the cereal fraction of liquid diets and amino acid supplementation to reduce protein content of liquid diets).

The detailed work involved measurements of all inputs (for example, pigs, feed, labour, straw, water, energy and medicines), all outputs (for example, pigs, meat, effluent and farm yard manure) and losses (for example, deaths and removals).

Results from each trial were independently subjected to financial evaluation to determine the effects of feeding and housing on total cost of production.

The work also included detailed measurements of pig health and welfare, microbial sampling of the pigs and their environment focusing particularly on salmonella, emissions of dust and ammonia to the environment and effects on meat quality.

Within the programme, research centres carried out detailed studies on the refinement of standard operating procedures for liquid feeding, such as optimum dry matter levels, particle size and feed enzyme treatment.

This article summarises key conclusions arising from the Finishing Pigs Systems Research Programme, focusing primarily on the development and evaluation of liquid feeding technology for improved pig performance.

## Short troughs and straw

During the initial planning of the Stotfold finishing systems research facility there was intense but healthy debate over trough design and the need to demonstrate whether straw based housing and liquid feeding were compatible.

| | Feeding system | | P |
|---|---|---|---|
| | Liquid | Dry | |
| Time (%) | | | |
| Lying | 73.5 | 67.0 | ** |
| Sleeping | 58.5 | 52.5 | ** |
| Investigating | 21.4 | 26.3 | * |
| Other pigs | 7.5 | 9.4 | ** |
| Pen parts | 6.3 | 9.1 | *** |
| Toy | 1.1 | 1.5 | ** |

***Table 2. Pig behaviour under ad libitum dry vs. liquid feeding (Trial 1).***

| | Fully slatted | | Straw based | | s.e.d. | P | | |
|---|---|---|---|---|---|---|---|---|
| | Liquid | Dry | Liquid | Dry | | H | F | I |
| Liveweight (kg) | | | | | | | | |
| Entry | 36.26 | 34.98 | 32.02 | 33.48 | | 1.819 | * | |
| Final | 101.60 | 103.60 | 104.30 | 102.20 | | 1.065 | ** | |
| Feed intake (kg/pig day) | 1.75 | 1.90 | 1.75 | 1.80 | 0.029 | * | *** | * |
| Growth (g/day) | 785 | 777 | 807 | 730 | 13.6 | | *** | ** |
| FCR | 2.27 | 2.50 | 2.26 | 2.57 | 0.038 | | *** | |
| Cleanliness and hygiene score | 82 | 87 | 60 | 76 | | *** | *** | ** |

***Table 3. Growth benefits of liquid feeding under fully slatted vs. straw housing and effects on pig cleanliness and hygiene (Trial 1). H = Housing, F = Feeding system, I = HxF interaction.***

In terms of trough design, there were two schools of thought. One favoured the traditional long trough system so that intake and carcase fatnesses could be controlled without trough aggression and the other supported the installation of the ad libitum short trough system to enhance intake and speed of growth of low appetite modern lean genotypes.

Although the commissioned facility did not allow direct comparison of long vs. short troughs, our experience over four trials with the ad libitum short trough system was positive. Compared with ad libitum dry feeding, pigs fed liquid diets using a sensor controlled ad libitum short trough system showed increased daily gain, improved FCR without detrimental effects on carcase fatness and P2 variability (Table 1).

The ad libitum short trough system offered additional behavioural and welfare advantages over ad libitum dry feeding, in that pigs spent proportionally more time under restful behaviour and less time in directing their attention to other pigs and pen parts (Table 2).

Our experience with liquid feeding on straw was equally favourable, provided there was good drainage, dunging passages were scraped and fresh straw bedding provided daily.

In Trial 1, which was conducted during the summer months, growth advantages of liquid over dry feeding were found to be greater under straw housing (Table 3), probably due to alleviation of heat stress.

As expected, pig cleanliness and hygiene scores were poorer for liquid fed pigs on straw bedding, but

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***Table 1. Pig performance and carcase quality under ad libitum dry vs. liquid feeding (Trial 1).***

| | Feeding system | | s.e.d. | P |
|---|---|---|---|---|
| | Liquid | Dry | | |
| Liveweight (kg) | | | | |
| Entry | 34.14 | 34.23 | 1.286 | |
| Final | 103.00 | 102.90 | 0.753 | |
| Feed intake (kg/pig day)[1] | 1.75 | 1.85 | 0.021 | *** |
| Growth (g/day) | 796 | 754 | 9.6 | *** |
| Feed conversion ratio | 2.27 | 2.53 | 0.027 | *** |
| Carcase weight (kg) | 76.60 | 77.38 | 0.415 | |
| Backfat $P_2$ (mm) | 11.45 | 11.39 | 0.304 | |
| P2 variability (St. Dev, mm) | 2.19 | 2.02 | 0.151 | |
| Cost of production (p/kg deadweight) | 94.6 | 99.2 | | |

[1]Feed intake corrected to meal equivalents at 87% dry matter c

***Table 4. Performance and carcase quality of phase and single diet liquid fed pigs (Trial 2).***

| | Feeding system | | s.e.d. | P |
|---|---|---|---|---|
| | Single | Phase | | |
| Liveweight (kg) | | | | |
| Entry | 35.23 | 34.97 | 1.468 | |
| Final | 102.20 | 102.00 | 0.980 | |
| Liquid feed intake (kg/pig day) | | | | |
| High quality diet for a 30kg pig | 2.46 | 2.35 | 0.063\| | |
| Low cost diet for a 110kg pig | 5.72 | 5.56 | 0.133 | |
| Total | 8.18 | 7.91 | 0.117 | * |
| Growth (g/day) | 886 | 860 | 11.5 | * |
| Feed conversion ratio | 2.36 | 2.36 | 0.036 | |
| Carcase weight (kg) | 75.67 | 74.48 | 0.810 | |
| Backfat $P_2$ (mm) | 11.67 | 11.53 | 0.347 | |
| Cost of production (p/kg deadweight) | 85.8 | 86.4 | | |

| | Control | | Low protein | |
|---|---|---|---|---|
| | Actual | Expected | Actual | Expected |
| Crude protein (%) | 21.3 | 20.00 | 16.6 | 15.00 |
| Total amino acids (%) | | | | |
| Lysine | 1.011 | 0.990 | 0.930 | 0.960 |
| Methionine | 0.288 | 0.320 | 0.272 | 0.300 |
| Threonine | 0.760 | 0.730 | 0.657 | 0.650 |
| Tryptophan | 0.271 | 0.260 | 0.219 | 0.210 |
| Free amino acids (%) | | | | |
| Lysine | 0.024 | 0 | 0.351 | 0.356 |
| Methionine | 0.017 | 0 | 0.061 | 0.050 |
| Threonine | 0.020 | 0 | 0.151 | 0.144 |

[1]Results corrected to meal equivalents at 87% dry matter content

***Table 5. Crude protein and amino acid analysis[1] of control and low protein liquid diets (Trial 4).***

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this problem was generally restricted to summer months, as pigs attempted to wallow in the dunging passage to alleviate heat stress.

## Phase-feeding

With most dry feeding systems there is limited scope for introducing consecutive series of new diets in line with the changing requirements of the pigs as they increase in weight from 30kg to slaughter.

The development of fully automated computer controlled liquid feeding systems has made the theory of matching daily nutrients requirements a practical reality.

With a two tank/two pipeline system it is possible to proportion the delivery of two diets (high vs. low specification) at each trough so that the resulting blend has a nutrient specification that meets the average requirement of the pen group each day.

As pigs increase in weight, the higher specification diet is gradually replaced by the lower specification diet offering feed cost savings.

At this point, it is important to clarify the difference between phase-feeding as described above from the more common practice of 'step-feeding' where the diet is changed either once or twice at some fixed point during the growing and finishing stage, for example, at 50 and 70kg liveweight.

Whilst the theory makes perfect scientific and nutritional sense, our research showed that there were no performance or cost benefits from phase-feeding over feeding one diet from 35kg to slaughter at 102kg (Table 4). The weight of lean and fat produced per unit of nutrient input was exactly the same for phase and single diet fed pigs due to adjustments in voluntary feed intake at different stages of the growth curve.

Phase-feeding increased cost of production by 0.6p/kg deadweight, principally associated with the extra investment in additional feeding equipment (tank, pipeline and valves).

Although our research has demonstrated that a single diet offers the best cost option for liquid feeding systems, when installing a new system it may be prudent to build in the option of changing diets should there be a requirement to medicate feeds and ensure that withdrawal periods are met. Environmental legislation may also call for heavier pigs to be fed diets with reduced nutrient loading, such as protein and phosphorous content.

## Supplemented liquid diets

With the need to control nitrogen emissions, there is increasing interest in the use of synthetic amino acids (AA) to reduce dietary protein surpluses and, therefore, nitrogen excretion. This approach has been investigated with dry diets but has not been widely tested in liquid diets. Moreover, Danish experience has raised concern over the loss of synthetic AA (lysine and methionine) in liquid diets. Diets with an imbalance in AA profile will result in a loss of growth performance and feed conversion.

Our research showed that there was no loss of synthetic AA as we fully recovered supplementary lysine, methionine and threonine, even when natural fermentation was present (Table 5). This is at variance from the Danish experience and cannot be readily explained.

Although there was no degradation of synthetic AA, growth rate and feed conversion were poorer on the low protein diet (Table 6) indicating a loss of nutrient utilisation. Cost of production was, therefore, increased by 2.8p/kg deadweight by feeding the low protein liquid diet.

As expected and in-line with other studies, effluent ammoniacal N and ammonia emissions were reduced from rooms housing pigs fed the low protein AA supplemented diet, demonstrating the environmental benefits of this dietary strategy.

It is recommended that synthetic amino acids should continue to be used in the least cost formulation of liquid diets but their strategic use to reduce protein levels in liquid diets

| | Feeding system | | s.e.d. | P |
|---|---|---|---|---|
| | Control | Fermented | | |
| Liveweight (kg) | | | | |
| Entry | 33.95 | 33.07 | 0.886 | |
| Final | 103.20 | 100.70 | 0.777 | * |
| Liquid feed intake (kg/pig day) | 7.25 | 7.61 | 0.107 | * |
| Growth (g/day) | 844 | 818 | 11.0 | |
| Feed conversion ratio | 2.26 | 2.47 | 0.019 | *** |
| Carcase weight (kg) | 76.06 | 75.37 | 0.393 | |
| Backfat P2 (mm) | 10.87 | 11.97 | 0.142 | *** |
| Cost of production (p/kg deadweight) | 93.6 | 113.8 | | |

***Table 7. Performance and carcase quality of pigs under natural vs. controlled fermentation (Trial 3).***

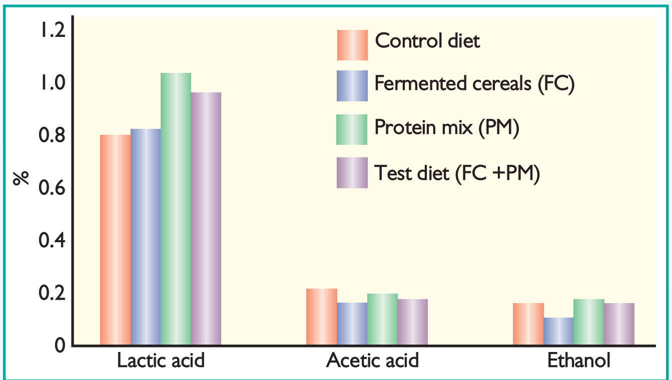
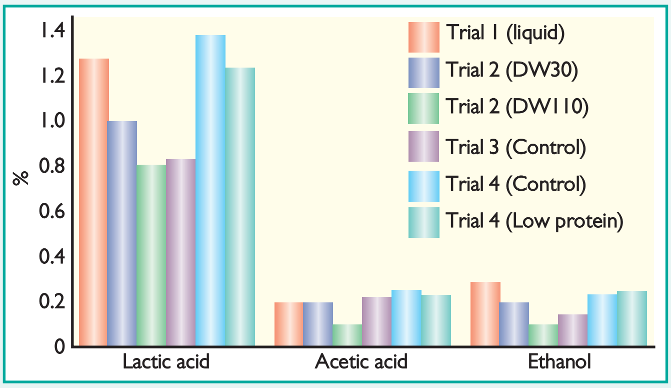



***Fig. 1. End products of fermentation in the cereal fraction of the liquid diet fermented with Pediococcus acidilactic, compared with a liquid diet and a protein mixture undergoing natural fermentation (Trial 3).***

***Table 6. Performance, carcase quality and environmental impact of pigs fed a control and low protein liquid diet (Trial 4).***

| | Feeding system | | s.e.d. | P |
|---|---|---|---|---|
| | Control | Low protein | | |
| Liveweight (kg) | | | | |
| Entry | 34.26 | 34.45 | 1.223 | |
| Final | 101.34 | 100.93 | 0.914 | |
| Liquid feed intake (kg/pig day) | 8.03 | 8.35 | 0.129 | * |
| Growth (g/day) | 851 | 821 | 11.5 | * |
| Feed conversion ratio | 2.49 | 2.68 | 0.039 | *** |
| Carcase weight (kg) | 76.72 | 77.95 | 0.400 | ** |
| Backfat P2 (mm) | 12.22 | 12.77 | 0.229 | * |
| Cost of production (p/kg deadweight) | 87.3 | 90.1 | | |
| Effluent ammoniacal N (mg $NH_4$-N/kg) | 4150 | 3530 | | * |
| Ammonia emission (g $NH_3$-N/lu hour) | 1.11 | 0.73 | | *** |

***Fig. 2. End products of natural fermentation in liquid diets over four trials.***



| | Trial 1 | | Trial 2 | Trial 3 | | Trial 4 | |
|---|---|---|---|---|---|---|---|
| | Dry | Liquid | Single Phase | Control | Fermented | Control | Low protein |
| Caecal (% positive) | 39 | 23 | Only 9 pigs tested positive from a total of 695 sampled | 3 | 1 | 5.6 | 1.7 |
| ELISA (% positive) | 35 | 16 | 6 6 | 6 | 3 | 28.6 | 19.6 |

***Table 8. Salmonella antibody levels and the presence of salmonella in the gut at slaughter.***

for environmental reasons should be met with caution until further research is carried out to establish how a loss in feed efficiency can be avoided.

## Feed processing

There has been much interest in managing the fermentation of liquid feeds by inoculation with selected strains of lactic acid bacteria at a constant temperature of around 30-35°C for a set time, such as 24 hours. Controlled fermentation contrasts with fermentation which occurs naturally in almost all liquid feeding systems irrespective of operating conditions. Selectively fermenting the cereal fraction of liquid diets under controlled conditions is considered to reduce the risk of malfermentation, which is increased by the presence of protein rich ingredients such as fish and soya bean meal.

Our research showed that there were no pig performance or cost benefits from selectively fermenting the cereal fraction of liquid diets for growing/finishing pigs under controlled conditions (35°C) for 24 hours using a lactic acid bacteria (Pediococcus acidilactici). Feed conversion was poorer, carcase fatness was increased and cost of production was 20.2p/kg deadweight higher in pigs fed a liquid diet containing fermented cereals compared with pigs fed the same diet without a managed fermentation process (Table 7).

Fermenting the cereal fraction did not significantly improve the fermentation profile of the liquid feed over and above that achieved from natural fermentation (Fig. 1). Natural fermentation is universal to most liquid feeding systems, as found in four major trials spanning over three years at MLC's Stotfold Pig Development Unit.

Natural fermentation generates desirable end products, such as lactic and acetic acid, which enhance gut health, improve growth rate and feed conversion and inhibit pathogenic and zoonotic organisms including salmonella.

At Stotfold, the amount of lactic acid produced under natural fermentation was around the optimum range of 0.7 to 1% (maximum 1.5%) for the control of salmonella and this may work in synergy with acetic acid, which is present at around 0.2% (Fig. 2). Levels higher than 1.5% for lactic acid and 0.2% for acetic acid may suppress intake through a loss of palatability.

As with all food and feed processing systems there are risks of undesirable outcomes. In on-farm liquid feeding systems, malfermentation presents such a risk resulting in feed rejection, reduced intake and loss of feed conversion efficiency. Although this is rare daily vigilance is important so that any abnormalities or signs of malfermentation are quickly detected.

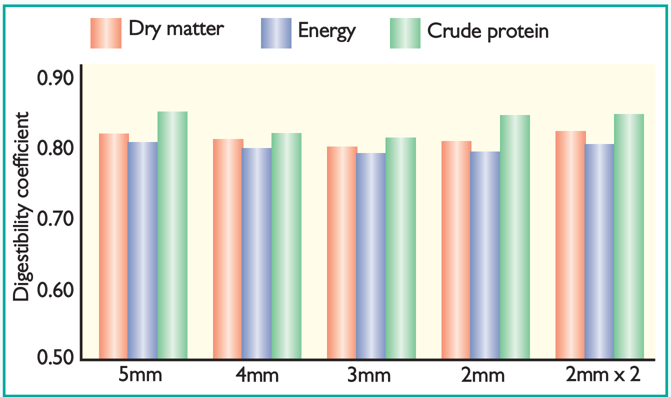



***Fig. 3. Digestibility of liquid diets containing cereals milled through different hammer mill screen settings.***

## Salmonella control

The Stotfold trial has confirmed other published studies on the positive effects of liquid over dry pellet feeding in reducing salmonella antibody levels and the presence of salmonella in the gut at slaughter. Caecal carriage remained low in subsequent liquid feeding trials and there was a significant and positive benefit from reducing protein content (Table 8).

Reduced gastric ulceration and gut coliform counts (Table 9) provide additional evidence that liquid feeding enhances overall gut health. In turn, this may explain why liquid feeding improves growth and feed conversion, and suppresses salmonella in finishing pigs.

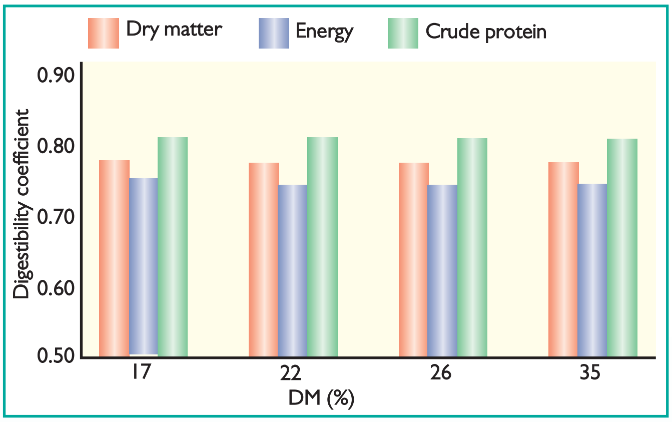



***Fig. 4. Digestibility of liquid diets differing in dry matter content.***

## Particle size

Our research showed that in terms of nutrient digestibility in the pig, there were no major differences when the cereal fraction of liquid diets was milled using screen sizes of 5, 4, 3 and 2mm or even double milling through a 2mm screen (Fig. 3).

This would imply that differences in particle size generated by these milling treatments (Table 10) are unlikely to influence the growth performance of growing and finishing pigs fed liquid diets. As with all research it is dangerous to extrapolate these finding to other situations such as dry feeding or younger pigs where the response is likely to be fundamentally different.

Milling cereals for liquid diets at larger screen size setting may reduce power consumption, milling time and dust generation, but the physical characteristics and handling of the liquid feed may be adversely changed. For example, coarse milled cereals with a higher proportion of larger particle will settle out more readily than finely milled material.

Separation within tanks may increase energy consumption during initial stirring at motor start up and separation within pipelines may result in the delivery of an unbalanced diet at the troughs.

Separation within feeding troughs may encourage selective feeding

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| | Dry feeding | Liquid feeding |
|---|---|---|
| Gastric ulceration score (0 to 5 scale)[1] | 3.0 | 1.3 |
| Coliform counts (Log 10 cfu/ml) | | |
| Ileal | 8.33 | 7.55 |
| Caecal | 7.02 | 5.84 |
| Colon | 7.10 | 5.79 |

[1] Severity of ulceration increasing with higher score.

***Table 9. Effect of dry vs. liquid feeding on some measurements of gut health (Trial 1).***

***Table 10. Particle size distribution of cereal used in liquid diets and dry milled through different hammer mill screen settings.***

| Sieve size µm: | | 2000 | 1000 | 500 | 250 | <250 |
|---|---|---|---|---|---|---|
| Sample type | Mill screen | % Sample retained | | | | |
| Barley: | 5mm | 21.3 | 43.2 | 21.2 | 8.5 | 5.8 |
| | 4mm | 9.8 | 44.5 | 25.8 | 14.3 | 5.6 |
| | 3mm | 1.9 | 35.1 | 38.8 | 17.5 | 7.8 |
| | 2mm | 0 | 6.2 | 45.8 | 32.8 | 15.2 |
| | 2x2mm | 0 | 1 | 47.8 | 38.4 | 12.7 |
| Wheat: | 5mm | 7.4 | 33.7 | 28.7 | 21.2 | 8.9 |
| | 4mm | 6.2 | 31.5 | 26.7 | 21.0 | 14.5 |
| | 3mm | 0.5 | 30.4 | 31.2 | 23.3 | 15.5 |
| | 2mm | 0 | 8.5 | 39.3 | 30.6 | 21.6 |
| | 2x2mm | 0 | 2.2 | 29.6 | 48.4 | 19.8 |

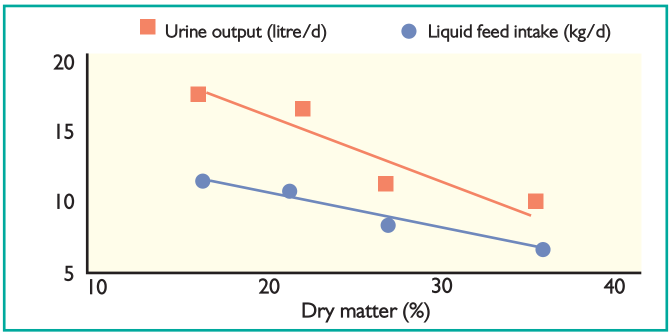


***Fig. 5. Effect of dry matter content of liquid diets on volumetric intake***

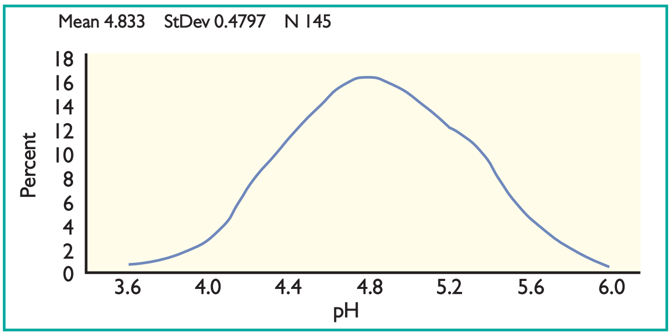


***Fig. 6. Distribution of pH measured in liquid diets with natural fermentation (A total of 145 samples taken from liquid diets over three years during the Finishing Pigs Systems Research Programme).***

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with pigs 'drinking' the top liquid fraction in preference to the settled solid fraction.

## Feed enzymes

Some ingredients, for example, wheat and particularly wheatfeed, are rich in naturally occurring phytase, the enzyme which releases phosphorous bound in phytic acid present in cereals and other plant feedstuffs. Our research shows that phytase is activated in liquid diets and is able to improve availability to over 90% of the total phosphorous present in the feed. The liquid mixture allows cross-reaction to improve the availability of phosphorous in feedstuffs lacking naturally occurring phytase such as soya bean and rapeseed meal.

Our work on other enzymes which target the fibre fraction of feed ingredients, the so called non-starch polysaccharide or NSP fraction, suggests that in liquid diets there is little or no evidence of their increased breakdown from the addition of NSP degrading enzymes.

We would conclude that there are limited advantages from the addition of feed enzymes, such as phytase, to liquid diets provided that the diet contains ingredients which are rich in naturally occurring phytase such as wheat and wheatfeed. It is important to note that natural phytase is sensitive to heat damage so where wheatfeed has been processed using high temperature pelleting, the activity of the phytase may have been significantly reduced.

## Dry matter content

There is no universal optimum value for the dry matter content of liquid feeds for growing and finishing pigs. Each system will have different ingredient, milling, mixing, feed delivery and trough design features which will influence the behaviour of liquid feed according to dry matter content. Some systems may easily handle feed containing 25% dry matter, others may struggle, requiring a reduction to 20% dry matter.

Our laboratory based studies suggest that there are no major differences in the digestibility of liquid diets, with dry matter levels ranging between 17 and 35% (Fig. 4).

This implies that the growth performance of pigs is unlikely to be influenced by normal daily variations in dry matter content and it is possible to operate over a wide range without negative effects provided the system can cope and the feed is delivered and eaten homogeneously.

Under ad libitum feeding and within limits, growing and finishing pigs can readily adjust their volumetric intake according to changes in dry matter content to achieve a constant dry matter intake (Fig. 5).

Volumetric increases in liquid feed in response to reductions in dry matter content are associated with increased urine production, resulting from increased water consumption and continued though reduced contribution from drinking water. For every 1% reduction in dry matter, urine production will increase by about 0.5 litres per pig per day, representing an additional 160 tonnes of effluent per year from a 1,000 pig place grower-finisher unit. The water, storage and disposal costs associated with this volume of effluent are not insignificant and will add to the overall cost of production.

## Monitoring pH values

Low pH values are an indicator of acidity and generally acidification through natural fermentation is desirable for gut health and salmonella control.

Monitoring pH daily is a sensible management procedure and natural fermentation should result in a pH value averaging around 4.8 (Fig. 6) but this will vary depending on background acidity of feed ingredients. The nature of the fermentation and its end products are more important than pH and these cannot be accurately predicted by simple pH measurements on farm. Samples should be taken regularly (for example monthly) and sent for laboratory analysis for the determination of lactic and acetic acid concentrations against recommended targets (see previous), but this can be a costly procedure.

## Cost of production

The ultimate goal of the research and development programme was to establish the contribution that liquid feeding technology could make towards the BPEX road to recovery target of 15p/kg deadweight reduction in the net cost of production.

We can conclude, from the results of four major statistically and scientifically robust trials involving over 4,000 pigs, that liquid feeding can reduce cost of production by a net of 14p/kg deadweight, of which 5p is associated with improved performance and 9p is derived from the inclusion of low cost industry co-products.

If a cost benefit of around 5p/kg deadweight is realised under commercial production, then the capital investment will be recovered within 2.6 years for a 2,000 growing/finishing place unit (Table 11).

This time scale would be considerably shortened if further cost savings can be made from the use of liquid co-products. Producers who have recently invested in liquid-feeding technology have confirmed that our pay back time scale is realistic and achievable.

***Table 11. Cost savings and estimated payback period for liquid feeding.***

| | Dry feeding | Liquid feeding |
|---|---|---|
| **Physical performance:** | | |
| Daily gain (g)[1] | 754 | 796 |
| Allowed days to gain 75 kg[2] | 102 | 96 |
| Days per batch (including wash down) | 109 | 103 |
| Pigs per year[3] | 6,697 | 7,087 |
| **Capital investment:** | | |
| Feeding system (£) | 5,300[4] | 64,420[5] |
| Cost of production[6] (p/kg deadweight) | 99.2 | 94.6 |
| **Liquid feeding compared with dry:** | | |
| CoP saving per kg deadweight (p) | 4.6 | |
| CoP saving per pig (£) | 3.54 | |
| CoP saving per year (£) | 25,088 | |
| Payback period for liquid feeding system(years) | 2.6 | |

[1] Trial 1 Finishing Pigs Systems Research (MLC, 2003). [2] From 30kg to slaughter at 105kg liveweight. [3] Within a 2,000 pig place unit. [4] Dry feeding system with bin, centreless auger and feeders. [5] Liquid feeding system with hammer mill, plus elevator and installation (£8,500), central processing unit of bins and augers for three cereals, two proteins and oil, with processing tank and controls installed in a new building (£42,300), tanks, pipeline and feeders (£13,620). [6] Cost of production (CoP) calculations include weaners, feed, labour, power, water, straw, mortality, waste management and capital investment, and assumes the following based on current trade quotes: (1) Building costs of £193/m2 for straw base and £227/m2 for fully slatted housing; these are the same for dry and liquid feeding systems. Building capital costs are depreciated over 25 years at 6% interest, with repair/maintenance costs at 2%. (2) Capital cost of feeding equipment is depreciated over 20 years at 6% interest, with repair/maintenance costs at 4%.

## Key conclusions

Liquid feeding can:

- Reduce cost of production by a net of 14p/kg deadweight, of which 5p is associated with improved performance and 9p is derived from the inclusion of low cost industry co-products.
- Reduce salmonella carriage in the gut of finished pigs at slaughter.
- Offer potential benefits to growing/finishing pig health and welfare.

This material was first presented at the Society of Feed Technologists? Pig Performance Conference. Full reports on each of the trials can be downloaded from the BPEX website: www.bpex.org.uk