Science delivery and cost in the pig industry – the British experience

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The Global View

At the global level there is a huge challenge ahead to provide food for the increase in the world's population which is projected by the United Nations Food and Agricultural Organisation (FAO, 2006) to rise from 6.5 billion in 2007 to 8.1 billion by 2025. Over the same time period it is projected that increasing wealth per capita will hasten further the current rapid transition to eating meat. Of all the meats available, pig meat is the most highly consumed meat in the world today:

Global per capita consumption (kg/head/year):

	2000	2015
Pig meat	14.6	15.3
Poultry	10.2	13.8
Bovine	9.8	10.1
Other	1.8	2.1

(Source: FAO, 2007)

Although FAO predicts stability in consumption, some commentators suggest that pig meat consumption will continue to increase in the future. For example, Roppa (2006) estimated that there will be a rise in pig meat consumption of 16.7% from 2006 to 2015. In addition to its popularity, pig meat has significant advantages over meat from ruminants as its production is 184% more efficient than intensive feedlot beef and 221% more efficient than intensive fat lamb production when measured as the meat output from a unit of cereal-producing land (Wiseman, Varley, Knowles and Walters, 2005).

The British Industry

The economic value of the British pig industry can be measured in several ways. According to the data from the British Pig Executive (BPEX) the value of pigs going for slaughter in 2006 (the last fully normal audited year) was £687 million, while retail sales of pork and bacon was £7.4 billion supporting a per capita national annual consumption of 25 kilograms of pig meat. In 2006 the values of exported pork, bacon and processed pig meat were £98.4 million, £24.6 million and £29.7 million respectively, totaling more than £150 million. In addition, the value of live pig exports was £14.1 million.

The industry leaders, such as BPEX and the British Pig Association (BPA) are pledged to ensure that the industry achieves the following:

- It is internationally competitive, cohesive and profitable at all stages in the production and the processing chain.

- It embraces new ideas from a broad range of sources, invests in its future, anticipates consumer needs and produces a range of convenient, healthy, tasty and safe pork and pork products.

- It is information-driven and communicates efficiently and effectively with others in the supply chain enabling it to meet customer requirements.

- It has an international outlook that enables it to compete effectively to exploit all available knowledge in production and processing and all available markets for pork, processed products and offal and breeding pigs.

- It exploits the high welfare standards of national production that continue to set this country apart from virtually every other country. Although there are planned some changes in sow housing legislation in the EU from 2013 with respect to housing pregnant sows in stalls, this does not go as far as the legislation currently in force in the UK that banned them in 1999.

- It ensures that pig production continues to make a positive contribution to the environment. Methane emissions are low and pigs consume and recycle non-meat co-products from the manufacture of human food and drink, thus reducing disposal problems in these sectors. The quantity of co-products is set to increase with the drive towards biofuels production and the pig is ideally positioned as a major consumer of these materials. Pig manure is of high potential value and can be readily recycled to arable crops. The pig's traditional role of converting plant-based co-products into both meat and manure is, interestingly, set to expand in the future.

Pig Progress

The increase in productivity from British pigs has been spectacular over the last forty years through improved management, nutrition, health and, in particular, genetics. Genetics is the first limiting factor in productivity and the British industry has led the world in pig genetics through the innovative and practical exploitation of quantitative and molecular genetics and the emergence and success of the world-renowned specialist pig breeding companies. These companies have been the focus of global pig improvement through the exports of British genetic material around the world.

The size of the improvements achieved over the last four decades can be judged by the comparative changes in mean performance at the commercial level. For the breeding herd, the number of pigs produced per sow per year has increased by 50%. At the commercial level, pigs eat some 33% less feed than their progenitors of some 50 years ago and produce more than 33% more lean meat. Overall, on a per tonne of feed basis, there has been a doubling of the amount of lean produced and a 50% reduction in the amount of manure produced per kilogram of lean produced (Plastow, 2007). As a result of these improvements, the costs of production have been significantly reduced and there has been a major reduction in the environmental footprint.

Role of R and D

The advancement and rapid evolution of the UK pig industry has been under-pinned by world-class science and there has been an exceptional record in the uptake of new technology as well as huge cost benefits from government and industry-sponsored R and D. These fit closely into key areas of the government Department for Environment, Food and Rural Affairs (DEFRA) and national science policy such as improvements in the efficiency of production, minimising environmental impact, promoting the highest standards of animal health and welfare, and the improvement of human health through quality assurance/HACCP schemes that are designed to minimise the transfer of food-born pathogens.

The delivery of determinable results from science depends on both pure and applied research and how the results of this research are taken up by the advisory and commercial sectors. By its nature as a primary producer, the pig industry is mostly concerned with the successful incorporation of research into productivity gains, but it is important to emphasise that, ideally, there should be a continuum between the various research arms. The success of recent join 50:50 funding between DEFRA and the pig industry is a very good example of this continuum. The typical range of R and D topics includes aspects of human nutrition and health, bio-engineering, feed processing, plant breeding for better nutrients, and aspects of animal and meat production. The key components are outlined below:

Areas for Pig R and D:

Welfare	Behavioural science, biological indicators of welfare, stress physiology.
Veterinary	Pathology, immunology, virology, bacteriology, diagnostics, epidemiology, vaccine development and vaccination, new drug development, zoonoses, biosecurity, disease surveillance.
Reproduction	Reproductive physiology, artificial insemination, sperm preservation and embryology.
Population Genetics	Population genetics, genotype development.
DNA Genetics	Molecular genetic approaches to pig selection.
Nutrition	Nutrient metabolism and nutrient requirements. Nutritional physiology and gut microbiology and immunology. Lean growth curves across genotypes. Growth modeling.
Carcass	Meat and eating quality. Food safety.
Meat Science	Understanding of the events and conditions encountered by the embryo, the live animal and the post-mortem tissue, which influence meat-eating quality.

(Adapted from the BPEX, 2004)

Specific examples of R and D projects that are driving solutions to needs particularly across the fields of health, nutrition, genetics and end product quality are outlined below.

The first is at the ‘cutting-edge’ of international research while the others indicate the nature of integrated research across scientific disciplines to establish specific advantages in consumer-driven traits of importance.

The Sanger Institute in Cambridge, primarily funded by the Wellcome Trust, is one of the world’s leading ‘high science’ research establishments. Here, collaboration between parts of the Human and Pig Genome Projects are working side-by-side establishing real opportunities for the UK as a world leader in these fields. On July 11th 2007 a ‘Physical Pig Map’ involving scientists from France, the UK and the US was published which was heralded as ‘The most highly continuous…map of any mammalian genome’ and an ‘Important model for human health particularly for understanding complex traits such as obesity and cardiovascular disease…and also has substantial economic importance for meat-based protein production. Physical clone maps have underpinned large-scale genomic sequencing and enabled focused cloning efforts for many genomes. Comparative genetic maps indicate that there is more structural similarity between pig and human than, for example, mouse and human”. The significance of this work is twofold – firstly, the speed of medical advances will be increased through the use of the pig ‘model’; secondly, through use of the pig genome map there will be faster genetic progress in specific pig production traits through the use of the latest molecular technologies.

Meat and eating quality are complex traits with large interactions between aspects of animal production and the treatment of animals post-farm, pre-slaughter and post-slaughter. Some of the results from key research undertaken recently in Britain are outlined below under specific areas.

Nutrition

The eating and keeping quality of pig meat is partially related to the fatty acid profile of the meat – this is readily influenced by the fatty acid profile of the feed and the total level of fat that is fed. Detailed recommendations to the industry are now available. For example, the recommendation is to have a minimum of 16g linoleic acid/kg, 20g poly-unsaturated fatty acids /kg and a maximum of 4g fish oil/kg for finisher pigs. High levels of vitamin E protect against rancidity in diets high in poly-unsaturated fatty acids and maintain the colour of pork on display while seleno-pork, which is marketed as ‘high health’ for the human diet, is produced by feeding animals selenium yeast. Unnatural taints from male pigs (referred to collectively as boar taint) cause consumer dissatisfaction with pig meat from non-castrated animals and is the result of two compounds produced by male pigs. One of these, skatole, can be modified through the reduction of tryptophan in the diet. This can be achieved by feeding coconut cake (at 100g/kg), sugar beet pulp (at 200g or more/kg), wheat bran (at 200g or more/kg), raw potato starch (at 100g/kg), lupins (at 100g/kg), chicory and protein sources that are readily digestible (such as casein). It has also been shown that maintaining good health is important for minimising taint as this reduces cell breakdown in the gut which increases tryptophan levels.

Genetics

To date, more than 1900 'viable' Quantitative Trait Loci (or 'blocks' of DNA that are closely linked to the genes that underlie a trait) have been reported that are associated with meat and eating quality. There are also three single genes (Halothane, RN and IGF2) that have a major effect on a range of important traits. In addition, genes have been identified for intramuscular fat, calpastatin (related to tenderness) and cortisol-binding globulin (which has different meat quality effects in different breeds). Apart from these, there appears to be an interesting relationship between subcutaneous fat depth and muscle tenderness and flavour. This may explain why 'traditional' breeds tend to have better meat and eating quality, as well as the fact that traditional breeds tend to have lower levels of white muscle fibres and higher levels of red muscle fibres. These observations, incidentally, are good examples of the importance of maintaining a diverse gene pool as minority breeds may well possess hitherto unidentified traits that remain to be assessed.

Genetics also plays a role in the control of 'boar taint' in entire animals as the level of the two causative compounds (skatole and androstenone) varies between breeds and between individual animals within a breed. In particular the Meishan and Duroc breeds tend to have higher levels of skatole than other breeds. A number of QTL and candidate genes have been identified for both skatole and androstenone, and the development of genetic markers is underway.

Practical on-farm and pre-slaughter strategies

The feeding of a low protein diet prior to slaughter helps to increase the amount of intramuscular fat or 'marbling' which improves eating quality by increasing tenderness and juiciness. Similarly, tenderness is improved in pigs with high birth and weaning weights and fast growth, thus breeding companies are actively selecting for these traits. Tenderness is also improved by feeding *ad lib* close to slaughter.

In general, the shorter the journey time to the abattoir, the better the meat and eating quality. There is also evidence that supplying straw on transporting lorries reduces fighting and stress. Once at the abattoir, a short time (one hour) in lairage prior to slaughter has been advised. However, latest research is suggesting that the most important factor involved in the maximisation of quality at this stage is the retention of pigs in social stable groups. A recent large-scale project has also suggested that flavoured water sprays (particularly orange squash!) may be important in minimising animal stress as pigs lick each other rather than fight.

With regard to future R and D, it is disappointing that the British industry is falling behind in investing in R and D in the livestock industries compared to major international competitors such as the US, Japan and Korea. For example, Genesis Faraday (one of 24 UK Government sponsored Partnerships which seek to improve the co-ordination between the research community and industry in specific market sectors) has collated data on R and D intensity which is a measure of the percentage of GDP spent on R and D. Among large pig population countries in Europe, the UK is behind Denmark, Finland, France, Germany, the Netherlands and Sweden. Interestingly, Genesis Faraday has analysed the participation in the EU Framework Programme 6 (FP6) and has shown that only 17% of industrial participants in FP6 were from the UK, lower than both France and Germany. Conversely, UK academia performed very well, receiving more funds than French and German academics combined. The cynic would say the EU is paying UK academics to do high quality research that is then commercialised elsewhere in the EU! Of course, it is excellent that our research base is so highly competitive but we need to ensure that Britain does more to ensure that we benefit from converting good science into profitable goods and services.

R and D cost benefit

In order to establish the likely cost benefit from R and D it is essential to know the level of national spend on projects and to have an evaluation of the production progress achieved. Unfortunately, it was very difficult to identify the national spend because of confidentiality limitations, problems with budget allocation because of co-funding and the difficulty of accurately splitting funds within programmes which are not species specific. However, through personal communications from Drs. Davies (DEFRA), Leask (UK Meat and Livestock Commission) and Williams-Blackwell (Biotechnology and Biological Sciences Research Council) the following lower and upper estimates for specific pig R and D funding in AU$ for 2005/2006 to 2007/2008 were obtained:

	2005/2006	2006/2007	2007/2008
Lower	7,358K	8,226K	8,038K
Upper	9,251K	9,688K	9,264K

With regard to benefit, Walters (2000) reported annual phenotypic gains to the UK industry over the fifteen years from 1984 to 1999. For the current report, these data were updated using national data from BPEX (BPEX, 2007) which covered the period 2001 to 2005. The annual gains in three key traits are shown below:

Trait	Annual phenotypic gain	AU$ Value/per pig
Litter size (pigs)	0.07	2.02
Growth rate (gm per day)	2.6	0.14
% lean	0.70	1.26

The annual value of improved performance was AU$3.42 per pig. Using the data on the UK slaughterings of 9,270,000 in 2007 (BPEX, 2008) the annual benefit from the improved performance was accordingly AU$31,703,400. Based on these data, the simple ratio of the average annual R and D spend (AU$9401K) to annual improved performance was 3.37:1. However, this takes no account of discounted cash flow, so a more detailed estimate of cost benefit for the British pig industry from R and D was evolved. Four models were used, two using the lower R and D cost estimate and two using the higher estimate. These were costed with a discount rate of 7% over 20 years with equal annual benefits showing from year four.

Models One and Two assumed that 25% of the phenotypic progress has been due to R and D, while Models Three and Four assumed 50%. For simplicity no account has been taken of differences in future slaughtering numbers or the time scale for R and D to be reflected in improved performance. The Models (see Appendix for an example) show that the ratios of the discounted benefit at the end of 20 years to the R and D investment are:

	25% 'return'	50% 'return'
Lower	1.93 to 1	4.79 to 1
Upper	1.46 to 1	3.86 to 1

These are similar to the R and D investment returns calculated for the Australian pig industry (Walters, 2006).

It is interesting to note that in 2004, BPEX commissioned a report on 'Longer-term priorities for the British Pig Industry' and showed that for a ten year investment of some AU£60 million the return was forecast to be some AU$900 million, resulting in a Net Present Value (NPV) of AU$360 million at a 15% discount rate. Furthermore, the report showed that the undiscounted benefit of R and D was AU$9.00 per pig for an investment of approximately AU$0.36 per pig.

The future

Recent DEFRA-funded modelling at the University of Cranfield demonstrates that selective breeding for efficiency of production also improves environmental performance of livestock systems per unit of food produced (Walters, 2008). This is excellent news as it is clear that the science and 'sustainable development' issues are important for the pig industry. DEFRA have 'Sustainable Development Dialogues' (SDDs), which are government-to-government dialogues on issues around sustainable development. It is unfortunate that none of them considers production agriculture in detail, demonstrating a worrying lack of understanding of the whole food production chain. The food supply component of this chain is facing enormous challenges in the very near future associated with high feed prices and the push towards biofuel production. For example, international government biofuel targets mean that within 15 years more than 12% of the world's agricultural land will be needed to support transport against just 2% in 2007 (Clover, 2008). The recent dramatic increase in the costs of feed raw materials without an associated increase in prices paid to pig meat producers has resulted in another crisis of confidence in the industry and a significant decline in the number of breeding animals. It should be borne in mind that the traditional approach of seeking cheap pigmeat imports from outside the UK is not a sustainable solution. Issues of biofuels, an increase in global population and affluence (that will result in an increase in pig meat consumption) will not only drive up the cost of pig meat but may even render the commodity in short supply. There is however a golden opportunity to include pig meat production within a SDD under the broad themes of 'sustainable consumption'.

The recent Foot and Mouth Disease scandal has confirmed that national biosecurity will be an increasingly important issue. Even though the number of infected premises was confined to eight, the disruption to the pig meat sector (attributable to movement restrictions) was financially very damaging, placing yet another burden on an already beleaguered industry. Whilst these problems may be seen by some as merely transient, the ability of the industry to absorb them is finite!

The UK is respected globally as being at the forefront of developments in animal welfare. Whilst some welfare developments have been, retrospectively, criticised (for example, the banning of sow stalls in 1999 was subsequently viewed by DEFRA as being unfair on the UK pig sector as it was not adopted by any other country and DEFRA agreed that it would not further introduce unilateral legislation), nevertheless welfare continues as a major consumer concern. There is also the important issue of welfare standards in countries exporting pig meat to the UK that are frequently below the minimum standards accepted in the UK.

In 2004, DEFRA sponsored an international conference at the University of Nottingham, on 'Yields of Farmed Species – Constraints and Opportunities in the 21st Century'. Global experts covering a wide range of socio-economic, environmental, plant and animal sciences were invited and the meeting was attended by policy-makes both from within the UK and overseas. The Proceedings of the conference formed part of the final report that was accepted by DEFRA. All the initiatives and innovations of UK agriculture over the previous 50 years were neatly encapsulated in the introduction that stated that 'UK agriculture has become one of the most sophisticated and productive in the world, but the transformation was a distant dream 50 years ago. More than a hectare of land was needed to feed each UK resident at the time of the 1st World War (about three times the available land area), whereas modern UK agriculture can now feed each of us from less than half a hectare, with food that is both inexpensive and of high quality. Despite an increased population, we have become 80% self sufficient in food, and a significant exporter of agricultural produce'. The introduction concluded that 'By foreseeing the important hurdles along the path we are setting, particularly towards sustainability, there should be scope not only to feed ourselves, but others too, and to share the landscape between productive agriculture and activities that need less resource'.

Whilst the meeting covered a wide range of commodities, principles could be applied specifically to the pig sector. The proceedings described the astonishing success of UK Agriculture (ranging from production itself but including the essential elements of research, development and knowledge transfer that have made UK Food Production the success it has been). In doing so, it has built up a world-leading base that is the envy of many other countries. It is to be hoped that continued official support for this base will allow further UK progress but also, equally if not more importantly, dissemination of our expertise elsewhere.

We live in a highly competitive global market, not just for food resources but also for technical services. Other countries are developing long term-strategies to maintain and raise their profile on the global food stage. For example, the United States Department of Agriculture (USDA) Foreign Agricultural Service announced in November 2007 that 'The USDA provided more than $234 million to help market American farm products overseas in the 2007 fiscal year. Promoting the product of the American farmer keeps the pathway open from the farm gate to the world markets. Satisfied customers around the world readily choose U.S. farm products once they have tasted the quality and experience the reliability of American agriculture. USDA establishes a trade promotion partnership with non-profit US agricultural trade organizations. Funding priority is given to organizations that represent an entire industry or are nationwide in membership and scope. Program activities focus on reducing market impediments, improving the processing capabilities of importers, modifying restrictive regulatory codes and standards in foreign markets, and identifying new markets or uses for US products'.

The UK pig industry (and the Australian industry) has the expertise and collective will to operate similarly and could continue its success at a fraction of the cost to the US taxpayer. Specifically the US awarded around $16 million to meat and genetics exports. However, UK (and Australian) pig genotypes consistently outperform (or equal) US counterparts (Walters, 2006). It is to be hoped that funds will continue to support UK pig R and D and overseas promotion so that this UK success story will be maintained far into the future.

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Appendix

Example of cost benefit function:

Appendix: £ Cost benefit from R and D - Model One[2]

Year	Discount Factor[o]	R and D Cost[1]	Return[2]	Net	Discounted Net	Discounted Sum
1	1.000	6,132,000	0	-6,132,000	-6,132,000	-6,132,000
2	0.9346	6,855,000	0	-6,855,000	-6,406,542	-12,538,542
3	0.8734	6,698,000	0	-6,698,000	-5,850,293	-18,388,835
4	0.8163	0	6,604,875	6,604,875	5,391,545	-12,997,289
5	0.7629	0	6,604,875	6,604,875	5,038,828	-7,958,462
6	0.7130	0	6,604,875	6,604,875	4,709,185	-3,249,277
7	0.6663	0	6,604,875	6,604,875	4,401,107	1,151,830
8	0.6227	0	6,604,875	6,604,875	4,113,184	5,265,014
9	0.5820	0	6,604,875	6,604,875	3,844,097	9,109,112
10	0.5439	0	6,604,875	6,604,875	3,592,614	12,701,726
11	0.5083	0	6,604,875	6,604,875	3,357,584	16,059,309
12	0.4751	0	6,604,875	6,604,875	3,137,929	19,197,238
13	0.4440	0	6,604,875	6,604,875	2,932,643	22,129,882
14	0.4150	0	6,604,875	6,604,875	2,740,788	24,870,670
15	0.3878	0	6,604,875	6,604,875	2,561,484	27,432,154
16	0.3624	0	6,604,875	6,604,875	2,393,911	29,826,065
17	0.3387	0	6,604,875	6,604,875	2,237,300	32,063,365
18	0.3166	0	6,604,875	6,604,875	2,090,934	34,154,299
19	0.2959	0	6,604,875	6,604,875	1,954,144	36,108,443
20	0.2765	0	6,604,875	6,604,875	1,826,303	37,934,746

[o] 7% over 20 years.
[1] BBSRC, DEFRA and MLC data.
[2] 25% phenotypic gain of £2.85 per pig on 2007 kill (9,270,000 pigs) from year 4.