# PRODUCTION CONTROL SYSTEMS FOR PIGS

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## ABSTRACT

Management control requires a production system to have, amongst other things, the following components: 1. Real time and continuous measurement of body size and weight change. 2. Response prediction models that can be optimised to particular production circumstance. 3. Feed systems that can deliver, upon instruction, stated quantities and qualities of feed to the pigs. Central to the control system is the ability to assess pig growth frequently (daily) and without physical interference. Visual Imaging provides such opportunity. The paper reports that Visual Image Analysis is sufficiently accurate to provide the required tool, and models can be fitted effectively to individual production circumstance by modulation of few parameters. It also appears probable that Visual Imaging may be able to sort pigs according to their type.

## INTRODUCTION

Growing pigs for meat is little different from other production processes:

- The rate of production (daily live weight gain) relates to the rate of input of the primary raw material (daily feed supply);
- The efficiency of production of the output is a function of the total quantity of input resource used (kg feed used per kg pig sold);
- Inefficiencies result in waste products (such as ammonia) that have disposal costs;
- The process is limited by the availability of the first limiting resource, which will likely be one of,
  - The quality of feed and of management inputs,
  - The ability of the pig to make use of the inputs presented to it;
- Management depends upon process control,
  - Production targets,
  - Measurement of the status of the product at any given moment,
  - The possibility of predictable correction of deviations from required performance.

Amongst management's tools would be:

- The genetic selection of the pig to grow high quality meat at the required rate and of the required ratio of lean to fat;
- The daily amount of feed supplied;
- The balance of energy to amino acid in the diet;

- The choice of the moment of slaughter (target size).

Effective use of these tools, and the decisions pertaining to their use, is necessarily an on-going (day-by-day) process, not least because:

- The amount of feed the pig requires changes daily as it grows;
- The balance of energy to amino acids required in the diet changes daily as the pig grows;
- Both of the above are affected by the ambient and the disease environment that fluctuates on a short time scale;
- The inherent potential of an individual batch of pigs is not well characterised at the point of entry into the grow-out unit;
- All the interacting elements of the production process are subject to short-term biological variation.

Presently, pig production is usually managed retrospectively, and not in real time. At worst, pigs are fed according to some general rules (nutrient requirements) pertaining to general populations and measured with pigs from various points in historical time. At best, pigs are fed according to the lessons learned from previous batches reared in like circumstances. Pig production systems therefore rarely use the available management tools to control the process and maximise the efficiency of production of meat of the required quality. There are three important reasons for this (Whittemore et al., 2001):

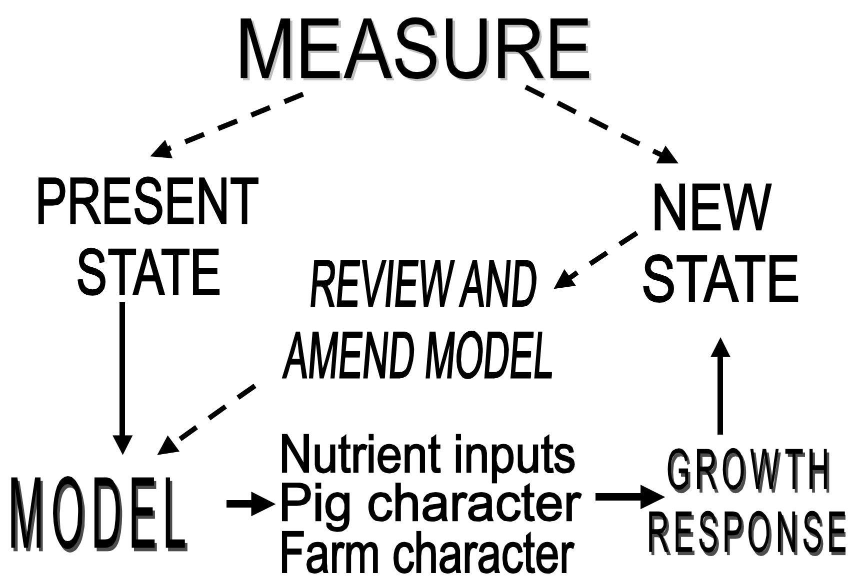
- The relationships between change in input (amount and quality of feed) and change in output (amount and quality of pig carcass) are inadequately known at the level of the individual production plant (farm). Such descriptors require to be flexed to fit the conditions prevailing to any given time, place and circumstances of production. There is a need for accurate and flexible models of pig nutrition and growth.
- The progress of the process is usually only poorly known. Short-term (and long-term) changes in growth rate are difficult to measure. The conventional (platform) weigh scale is not an effective tool for monitoring growth in the short term, and is not much used by managers for this purpose. There is a need for an effective way to monitor and measure the growth of pigs in real time.
- The most effective means of controlling the rate of pig growth and the fatness of the end product is by altering the amount and the composition of the feed supplied. As the deviations are in the short term, so also must be the corrective actions. Feeding systems that allow daily control of both amount and composition of diets fed are presently available. But they are rarely used to their full level because of inadequate monitoring of present positions of the pigs, and insufficient accuracy of prediction of consequences of changes to the pigs' diets. In the event, systems that can deliver variable quantities and qualities of feed on a daily basis are usually programmed to a preset pattern over the whole of the grow-out cycle. Computer-controlled feeding systems await management tools for their effective deployment.

In 1999 an applied research programme "**Integrated Management Systems for Pig Nutrition Control and Pollution Reduction**" was initiated to address these shortcomings in the effective control of the pig production process. It has just (2004) been completed, and the project is now going into active development with a view to commercial exploitation. This work has built upon previous basic research into video image analysis at the Silsoe Research Institute (Schofield, 1990; Marchant et. al., 1999; Schofield et. al., 1999). The IMS PIGS programme has involved research teams from Silsoe Research Institute (P. Scofield, D. Parsons, R. White), Edinburgh University (D. Green, A. Doeschl (PIC), C. Whittemore), Bristol University (A. Fisher, J. Wood) and ADAS (S. Carroll, R. Kay). The programme has been part of UK DEFRA LINK, and the industrial sponsors were Department for Environment, Food and Rural Affairs (DEFRA), Meat and Livestock Commission (MLC), BOCM Pauls Ltd., PIC (UK) Ltd., and Osborne (Europe) Ltd.

## THE IMS PIG MODEL

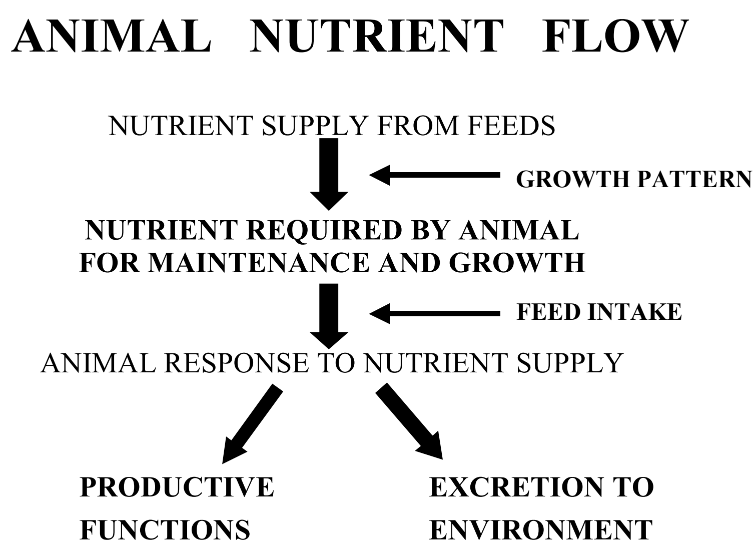
The details of the model have been reported by Green and Whittemore (2003). Its position in the management system is depicted in Figure 1.

**Figure 1. Positioning of response prediction model within a management control system.**




Importantly, the model is flexible enough to learn from its errors. Crucial to its use is an ability effectively to measure change in pig state. The model requires information on nutrient inputs, pig character and farm character. The structure is that shown in Figure 2. The IMS Pig Model links primary nutrients to tissue retention, determines variable efficiencies for energy and protein utilisation, and integrates nutrient cycling into a single system for maintenance and growth. These characteristics allow the model to be optimised on the basis of few parameter values. Recent findings have shown the model (like others before it) to be good at predicting the magnitude and direction of the growth response to nutrients, but poor at quantifying that response. Thus in a recent trial (Green et. al., 2004), the un-optimized model predicted end weight from the quantity and quality of feed input only to within 6 kg. [In effect, our ‘guess’ at the farm circumstances and the growth potential of the pigs was incorrect.] However, using the first half of the growth period to optimise the parameters $M_D$ and B, the model predicted end weight to within 1 kg of end weight. The parameter B is the lean tissue growth rate parameter, essentially describing the pig genotype. The parameter $M_D$ relates to the maintenance requirement for both energy and protein, and essentially describes the effects of disease upon the efficiency of nutrient use. Using the whole of the growth period to optimise $M_D$ and B, pig weight was predicted to within 0.5 kg of end weight. This showed that manipulating only two parameters could optimise the model, and when flexed, the model was sufficiently accurate to be used in a management control context for particular (rather than general) production circumstances. The parameter B is the lean tissue growth rate parameter, essentially describing the pig genotype. The parameter $M_D$ relates to the maintenance requirement for both energy and protein, and essentially describes the effects of disease upon the efficiency of nutrient use.

**Figure 2. A general description of the IMS Pig response prediction model.**




## VISUAL IMAGE ANALYSIS (VIA)

The visual imaging system uses simple video camera technology to capture the image of the back of the pig as the camera looks down upon the pig. From the image, linear measurements can be taken automatically. Further, and most importantly, mathematical algorithms developed at Silsoe Research Institute (Marchant et. al., 1999) allow the outline of the body to be traced and quantified. Thus the area described by the outline of the pig (A4) can be determined. Early results showed that the relationship between the A4 area and weigh-platform weight was rather good (Figures 3 and 4). The original equation for “Large White x Landrace” pigs was:

**Large White x Landrace Live weight = 0.052A4 – 32.**

**Figure 3. Relationship between time (day) and the weight of a pig determined manually, and by visual imaging (VIA).**

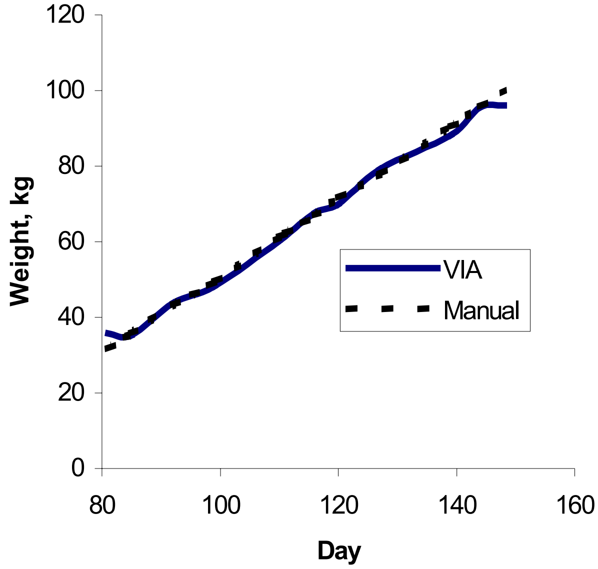
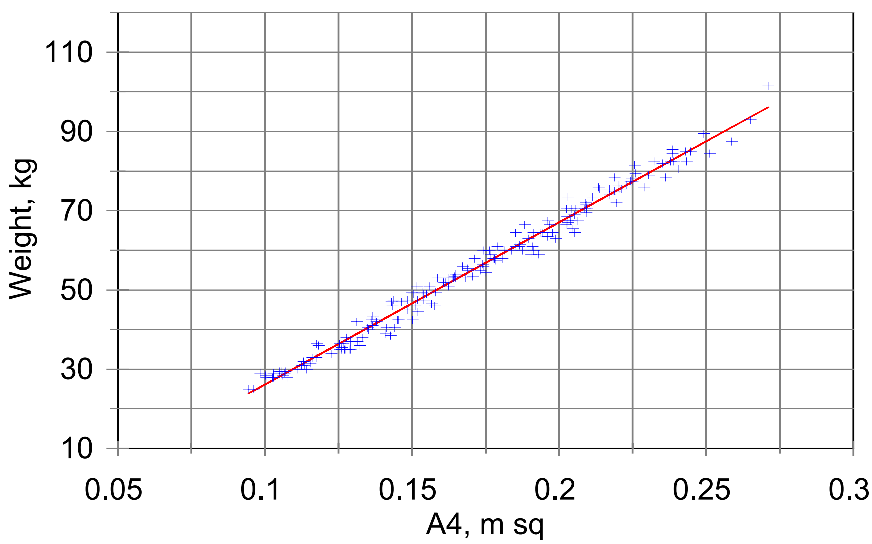



**Figure 4. Relationship between manual weight and A4 area.**




More recently (White et. al., 2003), the determination of this relationship was repeated in circumstances differing in time, place, research team and pig type. Three breed types were used; 25% Meishan, 50% Pietrain and 50% Landrace. The equations describing the relationship between A4 area as measured by visual imaging and live weight as measured by a weigh platform were:

**"50% Landrace" Live weight = 0.049(0.0005)A4 – 29.8(0.74)**

**“50% Pietrain” Live weight = 0.052(0.0004)A4 – 38.5(0.67)**
“25% Meishan” Live weight = 0.052(0.0004)A4 – 32.8(0.63).

We have interpreted these results as follows:

- The equations are robust;
- VIA A4 bears a close relationship to live weight, and by use of the equation can be used to determine live weight;
- As the equations differ between the pig types, it is important to be aware of pig type when setting up a system;
- As the equations differ between the pig types, it would appear the VIA system might be able to “identify” type differences. These could be important for carcass quality issues such as ham shape and joint proportions.

The most recent work, with Large White x Landrace pig types (again completed at a further different place and time, and with a different team), produced the following:

**Landrace x Large White Live weight = 0.049(0.0006)A4 – 34.1(1.15),**

which is similar to those determined for “Landrace” and Large White x Landrace pigs shown above. As all of these relationships were for pigs between 30 and 110 kg live weight, we further tested the relationship with heavier (Large White x Landrace) pigs, to find:

**“80 – 150 kg pigs” Live weight = 0.041(0.002)A4 – 33.8(6.0).**

It is yet to be ascertained whether the relative loss of precision and determination of slightly differing coefficients may be due to inherent (but stable) differences at higher live weights, or perhaps a tendency for curvilinearity in the line.

We believe that determining the status of pigs (size, shape, live weight) by VIA has advantages over a conventional platform weigher. Some of these are given in Table 1.

**Table 1. Advantages of VIA in comparison to conventional weigh scales.**

| Visual Imaging | Weigh Platform |
|---|---|
| Estimates weight | Measures weight |
| Measures size | Does not |
| May discern pig shape | Does not |
| May discern pig type | Does not |
| Remote from pig | In contact with pig |
| Does not require operative | Does |
| Can take continuous measurements in real time | Can not |
| Electronic | Mechanical |
| Technology will improve | Will not |

For effective control of the production system it is germane to ask how many days require to elapse between two estimates of weight before a safe determination of weight change can be made. Results are given in Table 2, from which it would appear that the VIA system requires only one more day than the weigh scale.

**Table 2. Number of days elapsed until expected change in pig size becomes significant, for conventional platform weigher and VIA A4 data, assuming confidence limits of 80 % and 95 %.**

| | | '25% Meishan' type | '50% Pietrain' type | '50% Landrace' type |
|---|---|---|---|---|
| Weigh-platform | 80 % confidence | 3 | 2 | 4 |
| weight | 95 % confidence | 12 | 4 | 13 |
| VIA A4 size | 80 % confidence | 3 | 4 | 5 |
| | 95 % confidence | 8 | 9 | 10 |

The (albeit small) between-type differences in the relationship between weight and VIA A4 (above) left us with the possibility that the visual image could be used to sort animals on the basis of their shape. On the assumption that type ("25% Meishan, 50% Landrace, 50% Pietrain) was a reasonable description of shape (which would not always be the case due to natural variation within types), a neural network was used to test this hypothesis. Half the animals were presented to the network with a statement of their type together with the full data set for each pig from VIA. This was then used to sort the remaining half on the basis of the VIA data only. The results are presented in Table 3. The accuracy of prediction was high (73%, 83%, and 64%), particularly for the 50% Pietrain and 25% Meishan types. These types were also rarely confused.

**Table 3. Confusion matrix for pig type.**

| Predicted type | Observed type | | |
|---|---|---|---|
| | '25% Meishan' | '50% Pietrain' | '50% Landrace' |
| '25% Meishan' | 72·5 % | 4·2 % | 17·1 % |
| '50% Pietrain' | 7·7 % | 83·0 % | 18·7 % |
| '50% Landrace' | 19·8 % | 12·8 % | 64·3 % |

## CONCLUSIONS

It is proposed that effective control of the pig production process is hampered by lack of the means to accurately determine, continuously and in real time, change in pig performances and deviations from targets. The evidence presented suggests the Visual Image Analysis may provide the resolution. Management assumes a realistic expectation of outcomes of corrective interference in particular farm circumstances. This can now be provided through the medium of a model that can be flexed through two (only) parameters. It would also appear that VIA could inform about pig shape, which may have benefits for carcass appraisal. The next steps will be to link the model and the VIA system to automatic computer-operated feeding systems which can control feed level and feed quality. When this step is complete, managers can not only be informed about and diagnose unwanted deviations in the production process, but like managers of other production processes, can also take timely remedial action.

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