Precision Livestock Farming: Precision feeding technologies and sustainable animal production

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Abstract: In order to be able to produce safe, uniform, cheap, environmentally- and welfare-friendly food products and market these products in an increasingly complex international agricultural market, livestock producers must have access to timely production related information. Especially the information related to feeding/nutritional issues is important, as feeding related costs are always significant part of variables costs for all types of livestock production. Therefore, automating the collection, analysis and use of production related information on livestock farms will be essential for improving animal productivity in the future. Electronically-controlled livestock production systems with an information and communication technology (ICT) focus are required to ensure that information is collected in a cost effective and timely manner and readily acted upon on farms. New electronic and ICT related technologies introduced on farms as part of Precision Livestock Farming (PLF) systems will facilitate livestock management methods that are more responsive to market signals. PLF technologies encompass methods for electronically measuring the critical components of the production system that indicate the efficiency of resource use, interpreting the information captured and controlling processes to ensure optimum efficiency of both resource use and animal productivity. These envisaged real-time monitoring and control systems could dramatically improve production efficiency of livestock enterprises. However, further research and development is required, as some of the components of PLF systems are in different stages of development. In addition, an overall strategy for the adoption and commercial exploitation of PLF systems needs to be developed in collaboration with private companies. This article outlines the potential role PLF can play in ensuring that the best possible management processes are implemented on farms to improve farm profitability, quality of products, welfare of animals and sustainability of the farm environment, especially as it related to intensive livestock species.

Keywords: Precision Livestock Farming (PLF), precision feeding, control systems, automation, software-based technology, sensors, nutrition, pig farm

DOI: 10.3965/j.ijabe.20120504.00?

Citation: Banhazi T M, Babinszky L, Halas V, Tscharke M. Precision Livestock Farming: Precision feeding technologies and sustainable animal production. Int J Agric & Biol Eng, 2012; 5(4): —.

1 Introduction

Advanced information management is increasingly an essential component of profitable livestock production[1-4]. However, the so-called Precision Livestock Farming (PLF) or Smart Farming concept is in its embryonic stages and is continuously evolving[5-8].

Received date: 2012-06-26 **Accepted date:** 2012-12-13

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The main purpose of PLF is to enhance farm profitability, efficiency and sustainability by improving on-farm acquisition, management and utilisation of data that can be used for improving the nutritional, environmental and other management aspects of various livestock species[9-11]. Thus PLF potentially also provides a framework to "enforce" the application of best practice management/nutrition on farms and therefore reduce the variability observed in inputs and outputs, such as the varied quality and quantity of meat, milk, egg, wool, etc.[12]. PLF could also deliver additional food hygiene, traceability, welfare and environmental benefits[13]. Information captured on and off farm can be used to improve the traceability of livestock products and thus improve food safety standards[14]. Information captured routinely on farms that can be related to the welfare of animals via the documentation of living conditions encountered in livestock buildings can be used for quality assurance purposes[15]. This type of information can also be used to make producers aware of the likely environmental impact of their farming operations[16].

Progress in PLF was facilitated by the significant improvements achieved in computer processing power and the availability of different sensor technologies that are usually 'borrowed' from other industries[13,17,18]. The following three main steps are the crucial components of any successfully developed PLF systems, namely the identification of (1) measurement, (2) data analysis, and (3) appropriate control systems, which will form part of the integrated system.

Firstly, the measurements have to be identified that facilitate the most important decision making processes on farms. These measurements will be primarily the nutritional input and environmental conditions that are required to maximise economical/biological efficiency and therefore enhance profitability and productivity[9]. This follows with the identification of appropriate data analysis and interpretation systems that allow decisions to be made from the collected data. In this stage, nutritional or biological models need to be developed. Finally, electronic or other appropriate control systems have to be identified which activate control actions based on the analysis of the recorded data. These three components are then merged into an integrated system with appropriate communications links to pass information smoothly among the main components.

2 Factors influencing the successful application of PLF systems on farms

It is essential that users of PLF systems understand the underlying decision making processes on their farms and the impact of these processes on profitability and sustainability. In most cases that would largely involve the understanding of the nutritional requirements of the animals as they grow over time[9]. In addition, a very good understanding of their environmental requirements will also be important. It is important to define and set precise ranges for variables to be controlled, including required nutritional input. Such precise understanding of nutritional requirements will necessitate that a number of scientific principles work together (Figure 1) to achieve a better understanding of the nutritional needs of the animals.

Figure 1 summarises the envisaged relationship between natural, nutritional science and other related disciplines. The so called precision nutrition, applies the research findings of traditional nutrition as well as related areas of animal nutrition in order to meet the unique nutritional requirements of a specific group of animals kept under specific conditions with maximum accuracy[19]. For that purpose the following principles have to be considered:

(1) Use of a precise matrix for both nutrient requirement and nutrient content of the ingredients;

(2) Proper use of modifiers such as enzymes, prebiotics, probiotics, antioxidants, mould inhibitors and other feed additives;

(3) Exploiting genetic improvements in animals and feedstuffs;

(4) Reduction of toxicants and antinutritive factors;

(5) Use of improved feed and feedstuff processing techniques that will lead to better nutrient utilization[19].

Precision nutrition (also called "information intensive nutrition") is the practice of meeting the nutrient requirements of animals as accurately as possible in the interest of a safe, high-quality and efficient production, while ensuring the lowest possible load on the environment[20].

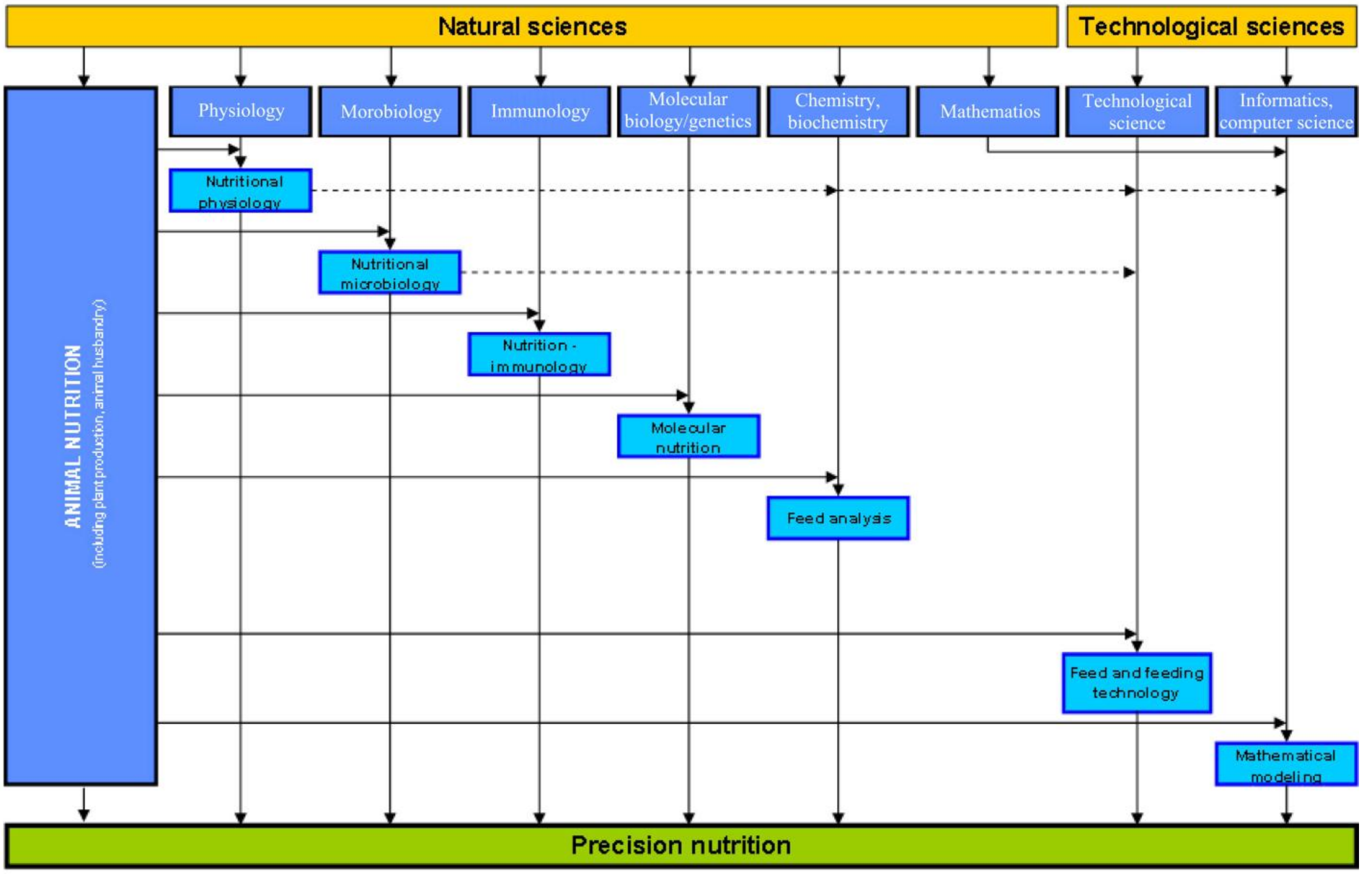

Figure 1 Relationship between natural, nutritional sciences and other related disciplines[19]

In order to facilitate the practical implementation of the PLF systems on farms, it will be important to develop fully integrated system and provide all system components to end-users as explained in a related publication[5]. The current practice of promoting the utilisation of individual PLF system components and expecting the users to integrate disjointed components is unsustainable and counterproductive[5]. The suggested system integration approach would also mean that, where possible, the utilisation of existing hardware and software components/products needs to be considered. If system components are independently developed and the components compete with existing products, it is likely that PLF developments and implementation on farms will fail. Perhaps a new service industry needs to be developed, which will assist producers with the installation, maintenance of hardware deployed on farms and with the interpretation of data acquired from these systems[14].

The need for human intervention and/or data transfer within the system has to be minimised. If human intervention is inevitable, then standard operating procedures (SOPs) have to be developed in advance and have to be implemented as soon as the events trigger the required action. One of the important aspects of PLF is to reduce the need for frequent intervention and automate both data collection as well as control functions on farms. This will reduce the reliance of livestock operators on scarcely available farm labour. On the positive side it will also free up the time of livestock managers enabling them to undertake more important tasks, such as the frequent monitoring of livestock.

3 Technological tools used on pig farms

Different devices can be used to obtain data in livestock facilities. However, specific variables should only be measured if they have been identified as important for improving efficiency and competitiveness of enterprises[5,21]. These include the measurement of live weight gain[15], feed intake[22,23] and environmental data[24].

3.1 Live weight measurement: Weight-Detect™

The measurement of average live weight gain (speed of growth) of a distinct group of animals, including pigs for example, is one of the most important measurements to be undertaken on livestock farm as the speed of growth will affect both the financial performance of the farming enterprise as well as the final body composition of the animals. Traditionally growth rate measurements are undertaken by periodically weighing a group of representative animals and calculating the growth rate by using simple arithmetic. However, this method is both time consuming and potentially stressful for workers and animals alike. Relatively recent systems appeared on the market (such as the Osborne Weight-Watcher™ system), which aimed at facilitating daily measurements of live weight gain by introducing a set of scales in an alley between the feeding and living sections of piggery buildings. However, the management challenges associated with operating these systems and the cost of the systems unfortunately limited their adoption on farms. Therefore, a number of projects have been initiated in various European countries, including Denmark[25] and UK[26,27], to develop live animal measurement systems using image analysis techniques. The technical challenges associated with operating image analysis systems under tough farming conditions and the variable lighting conditions present in farm buildings limited the adoption of these systems. However, recent studies undertaken in Australia (Figure 2) demonstrated the technical and to some extent the economic viability of these systems[15].

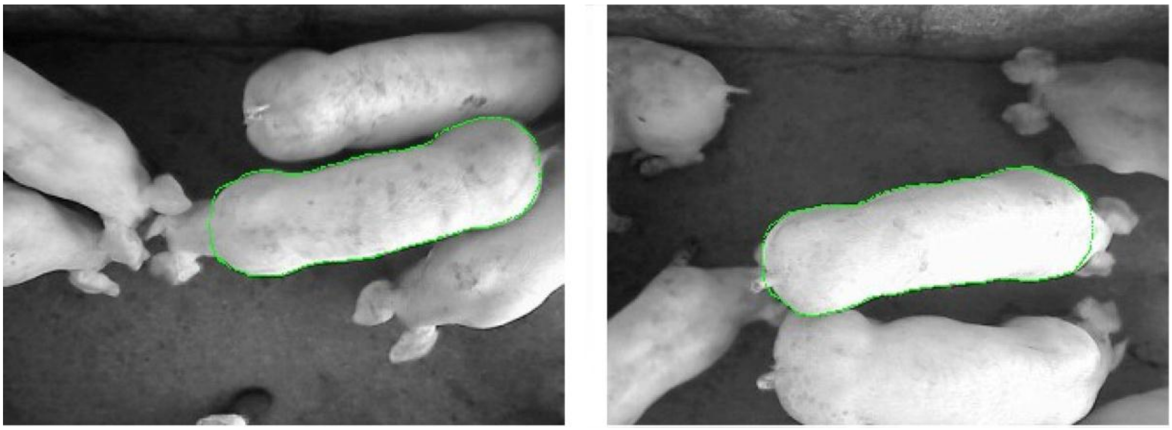

Figure 2 Some examples of images automatically obtained from an Australian farm by the vision system developed

Weighing system based on image analysis techniques are designed to determine the weight of individual or group of animals (specifically pigs) with acceptable precision by correlating dimensional measurements of the animals to weight. The results of recent studies conducted in Australia[15] demonstrated that such systems can reliably provide a performance record of successive batches of animals and in a timely manner (Figure 3).

In Figure 3, the results of an on-farm trial are presented[15]. The expected growth curve was established based on independent measurements and then the measurements taken daily by the image system were compared to the expected growth curve. A good correlation was demonstrated by the trial.

3.2 Measurement of feed usage: Feed-Detect™

Accurately and automatically measuring the amount of feed used per day per animal or distinct group of animals is extremely important, as the feed conversion efficiency (amount of feed used for the production of unit meat) is the main driver of profitability of all meat producing livestock enterprises. Although there are systems available that can measure the amount of liquid feed used for feeding; there are no commercially available systems that can be retrospectively installed on farms and be used to measure the amount of dry feed dispersed to individual feeders. In Australia, an innovative feed sensor was developed recently (Figure 4) that can quite precisely measure and control the amount of feed delivered to individual feeders[23].

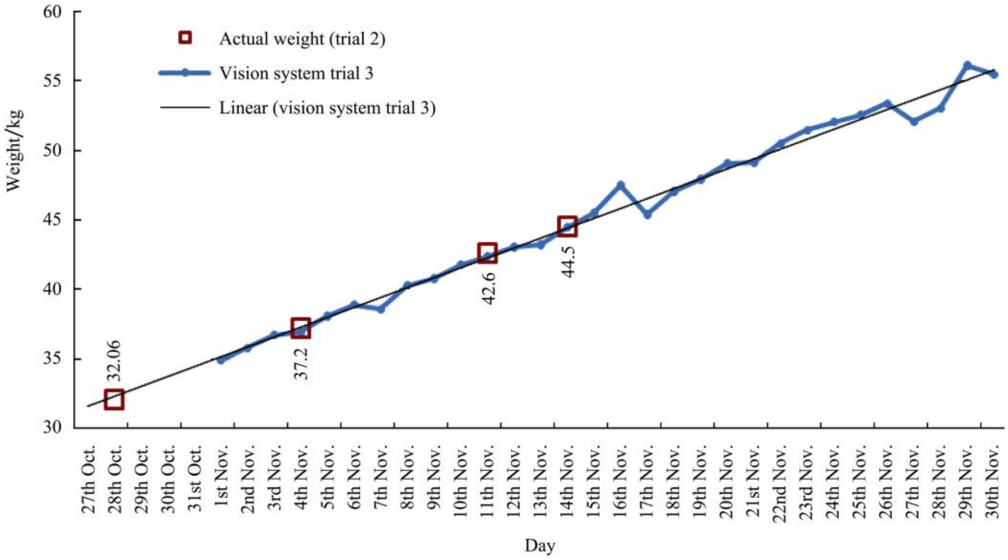

Figure 3 Average pen weights obtained and remotely downloaded from a commercial farm[15]

Figure 4 Prototype feed sensor and the camera system undergoing testing at a commercial piggery site[22]

3.3 Environmental data collection: Enviro-Detect™

Environmental (including air quality) variables are crucial information for the efficient management of piggery buildings. There is a strong emphasis on the management of thermal environment within intensive livestock buildings because it is well known[28] that animals are the most efficient converting feed to meat when kept within their respective thermo-neutral zone and the air quality is optimal. Thus, air quality related variables have to be measured as it has been demonstrated that these variables have a significant effect on production efficiency[29,30]. Information about important variables to be measured on livestock farms and their potential effects on production efficiency has been published before[29,31]. There is no commercially available system that measures all these parameters. For this reason an air quality monitoring instrumentation kit has been developed in Australia (Figure 5) to be incorporated into future PLF systems[24].

Figure 5 Environmental monitoring modules of the BASE-Q system[24]

4 Farm implementation and commercialisation of PLF systems

Unfortunately, current research and development (R&D) efforts are misaligned with commercial requirements. While considerable R&D effort is being expanded for sensor developments; there is inadequate R&D activity spent on Decision Support System (DSS) development that has to be the core of any PLF system. In addition, efforts aimed at developing intelligent control systems, including robotic systems, are highly inadequate.

However, business opportunities for a PLF package development (including the provision of complete systems, expert advice, training and general support) do exist, but very few companies have taken advantage of such opportunities. The main market barriers limiting the uptake of PLF systems are (1) lack of clearly demonstrated financial benefits, (2) concern regarding the reliability of components, and (3) difficulties with effective deployment of PLF systems[14]. The opportunities to remove these technology adoption barriers are discussed in a related publication[14] and include (1) the development of a new service industry, (2) farm demonstration of the economical benefits of using these technologies, and (3) enhanced collaboration between the research and commercial sectors.

Nonetheless, limited on-farm trials demonstrated in South Australia that the implementation of an embryonic PLF system can result in the dramatic reduction in carcass variability as well as improvement in both feed conversion and daily weight gain that can ultimately improve farm profitability[32]. To achieve higher level of PLF technologies adoption on farms, the involvement of commercial companies will be extremely important. Currently, only a handful of commercial companies offer assistance with the implementation of PLF type technologies on livestock farms. A greater level of commercial involvement in this field will be important for the future to ensure that farm managers will have access to information that can assist them to optimize their livestock production process and improve profitability of their farms.

5 Conclusions and recommendations

The main aim of PLF systems is to collect relevant information frequently and cost effectively about key aspects of livestock production (including growth rate, feed conversion efficiency and environmental conditions in livestock buildings) in order to ensure that optimal control of the production process can be achieved. These systems have to be developed to the extent that their commercial implementation can become a reality. However, before these technical opportunities can be realised, further work needs to be undertaken, which was mainly related to the complete integration of system components. Once the integration is completed, the commercialisation of these PLF systems needs to be licensed to suitably qualified companies that will be charged with the marketing of the technologies. It is only through the involvement of commercial companies that PLF systems can be readily made available to livestock producers.

Acknowledgments

Most of the underlining study reported in this article were funded by the Australian PORK CRC and were undertaken as a large collaborative project between the University of Southern Queensland (USQ) and the South Australian Research and Development Institute (SARDI). The projects involved the contributions of many individuals, and we wish to particularly acknowledge the professional advice of Dr. R Champbell from PORK CRC and Prof. D Berckmans from Catholic University of Leuven, Belgium.

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