Invited lecture
COBISS: 1.06
Agris category code: L01

LIVESTOCK PRODUCTION AS A TECHNOLOGICAL AND SOCIAL CHALLENGE – EMPHASIS ON SUSTAINABILITY AND PRECISION NUTRITION

Csaba SZABÓ [1], Veronika HALAS [1]

ABSTRACT

Feeding the world's growing population is one of the biggest challenges in the 21st century. As our natural resources are depleting and our nature changing due to the human activity – sustainability is an emerging issue. In short sustainable agriculture means a system which preserves the basis of life of future generations. In the case of animal production this includes the following key areas: providing sustainable feed base, reducing environmental impact, feed and food safety and sustainable intensification. Animal production systems can be intensified throughout the application of precision livestock farming (PLF) systems. As the majority of production expenses related to feed, precision nutrition is a key component in PLF systems. Precision nutrition includes the following principles: use of precise nutrient requirement matrix, use of precise ingredient matrix, proper use of modifiers and feed processing technologies and adjustment of nutrient supply to match requirements of livestock. The aim of this paper is to highlight the current standing and future perspectives of sustainable animal production and precision nutrition.

Key words: animal production / sustainability / precision nutrition

1 INTRODUCTION

Animal agriculture is facing a huge challenge in the 21st century. The world's population is estimated to reach 10 billion by the end of the century. However, not only the rise of the population, but also the improving living standards in fast developing countries like China and India increases the demand of food. The average increment rate of animal production is 1.6%/year (FAO, 2010) and by 2016 the demand for animal feed will be increased by more than 50% compared to 2006 (Farrell, 2009). Nevertheless, animal production also threatens our life on the Earth. We are competing for food and the excretion of nitrogen, phosphorous and methane contributes to damaging our nature. Therefore, sustainability is a key question in future animal production system.

In agriculture the first green revolution lasted between 1930–1970 aiming the revolutionary improvement of productivity (capacity and efficiency). Nowadays many speak about the second green revolution. However it has a different meaning depending on which country is considered. For countries with less developed agriculture it means improvement of yield and technology, while for countries with developed agricultural production it aims to achieve sustainable production. Sustainability can be termed differently and it has many aspects. At the Earth summit in 1992 the UN Food and Agriculture Organization (FAO) defined sustainable agriculture and rural development as follows: "Sustainable development is the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations." Such sustainable development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable. As the demand for food is increasing and the area of arable land decreases we continuously have to improve the

1 Kaposvár Univ., Guba Sándor út 40, 7400 Kaposvár, Hungary

efficiency of animal production. For that purpose one of the possibilities is applying precision livestock farming.

Therefore the aim of our paper is to highlight the current standing and future perspectives of sustainable animal production and precision nutrition.

2 SUSTAINABLE ANIMAL PRODUCTION

When we are talking about the sustainability of animal production in terms of preserving the basis of life for future generations the following key areas have to be considered:

- providing sustainable feed base
- reducing environmental impact
- feed and food safety
- sustainable intensification

2.1 PROVIDING SUSTAINABLE FEED BASE

Some news reported last summer that for the first time in history the US ethanol industry used more corn than consumed by animals. This clearly shows the situation that how big is the competition for feed materials which also suitable for both human consumption and industrial utilization. After industrial processing of the feedstuffs, usually a feedable by-product formed. Producers usually term these by-products as co-product and this slight difference reflects in the pricing. While in the past by-products were associated with low prices and were a means to reduce feed costs, nowadays their prices are tending to be similar to grains or even higher. However their nutritional value is usually lower (mainly due to the higher fibre and lower energy content) and the properties are different compared to the original raw material. Also, about 30–40% is "lost" in amount of available feed base compared to the weight of the raw materials. Therefore intensive research is needed to reveal all aspects of the efficient use of these co-products.

Due to the foreseen increased demand for compound feed we will face with shortage in protein sources as well. Due to the overfishing, the supply of fishmeal as the primary protein source of aquaculture industry is already questionable. However, there is a huge feed and food-production potential in the aquatic cultures. Various algae are considered to be seaweeds, but these plants contain high level of oil, which makes them a good raw material for biofuel production. The remaining co product or even the whole algae meal can be a good feed source for ruminants, monogastric species and fish and therefore intensive research is carried out (Carillo *et al*., 2012; Angell *et al*., 2012; Toral *et al*., 2012). Fraser Thomson representative of the McKinsey Global institute told at the AquaVision 2012 (Stavanger) conference, that aquaculture can potentially increase to meet the protein needs of 500 million more people. To achieve that we certainly have to change our eating habit as well. The improved utilization of sea water aquaculture will preserve our freshwater reserves.

The meat and bone meal had been banned from the diets of farm animals due to the bovine spongiform encephalopathy (BSE) disease. This caused less available protein feedstuffs, and an increased production cost. Unfortunately, the decision makers did not make distinction between the different products, as the conventionally treated (solvent defatted, autoclaved and dried) meal did not cause any proven BSE case. Nowadays the EU is reconsidering to allow the cross species usage of meat and bone meal. In that case we could have a dietary 2.5–3 percent good and price competitive alternative to soybean meal.

A new possible future protein source is the earthworm (Ebadi, 2009) and insects. The advantage is that agricultural and food wastes which cannot be used directly as feedstuffs can be turned into a valuable protein source. The major obstacle is the legislation and scaling up production to provide a competitive feed component.

These were only examples of possible contributors to have sustainable feed resources. There is certainly more opportunity we just have to walk with open eye and be receptive to new ideas.

2.2 REDUCING ENVIRONMENTAL IMPACTS

Manure disposal is a major problem in highly intensive farm animal production areas because of water and air pollution. Among farm animals the monogastric species excrete most of the nitrogen and phosphorus, due to the digestibility properties, protein and amino acid supply and improper manure handling. For instance sows, weaners and slaughter pigs excrete approximately 75%, 45% and 70% of the nitrogen, and 75%, 40% and 60% of the phosphorus consumed, respectively. In the case of Hungary about 34000 tons of N and 8000 tons of P can potentially pollute the environment yearly from the pig and poultry sector. This is about 5.0 kg of N and 1.1 kg of P per ha of arable land. These values are far below the legislation in France, Denmark and The Netherlands (Jongbloed *et al*., 1999). However, by improper manure and slurry handling the regional emission can be higher. Using dietary nutrient recommendations based on ileal digestible amino acids, ideal protein concept and digestible phosphorus can result about 20–30 percentage reduction in N and P excretion. Shifting recommendation from total P to digestible P will not reduce significantly the P emission in countries where the P emission per ha is quite low and legislation is not foreseen. The dietary inclusion of microbial phytase depends on economic considerations. We should not forgot, that the manure is a valuable natural fertilizer to the soil. It degrades gradually down in 4–5 years and provides not only the major elements to the plants, but the trace elements as well. The problem is that farms are specializing more and more, and the animal production is separated from plant production. Thus, the utilization of the manure as a valuable co-product is not solved in many places. More integrated agricultural systems or better co-operations with specialized farms (plant/crop and animal producers) has to be in order to use the resources efficiently and thus to reduce the ecological footprint of agriculture.

2.3 FEED AND FOOD SAFETY

During the past years we have experienced several food and feed safety scandals. By the continuous improvement of the field to fork chain traceability, these problems can be treated quite in time in Europe. Nevertheless, we are importing significant amount of feedstuff and food from third parties with less developed feed and food safety systems. Due to the globalisation where even a simple carrot travels thousands of kilometres from the producer to the consumer this can be a real source of danger.

However, the hottest issue nowadays is the usage of genetically modified organisms. These plants and animals offer advantages to the producer: tolerance to herbicides in order to improve the efficiency of weed control, protection against the damage of insects to save soil fertilization cost, improve the phosphorous digestibility, etc. At first sight these organisms has no adverse effect on nutritive value, animal performance or human health. They might not have; however, we need some caution based on earlier experiences with excellent solutions. Let's cite the story of antibiotics. Concerns about antibiotic resistance, especially associated with antibiotics that were used both in human patients and as growth promoters in livestock, led to the Swann Report (Swann *et al.*, 1969). In the report it was recommended that antibiotics used in human medicine should not be used as growth promoters. It is believed that by separating the human and animal antibiotics we will solve the problem of transborder resistance. But in about thirty years we have learned a new term – cross resistance. There is even a concern, that antibacterial agents used in households, food industry and in hospitals may play a role in the emergence of bacteria resistant to antibiotics. So what can we learnt from that? Not everything is gold that shines. Last year a Bt-corn-field (insecticide sweet corn) was completely damaged in the USA by the western corn rootworm which gets accustomed to the poison in the plant. Ermakova (2005) reported reduced growth of rat's offspring and more than 50% mortality among pups which mother fed GM soybean based diet. Earlier Ewen and Pusztai (1999) demonstrated reduced growth and damaged immune system of rats fed GM potatoes. Domingo (2000) summarized our knowledge in the field of GM safety: many opinions, but few data. Despite these and other cautionary results still insufficient attention is paid to this potential danger. Therefore it is needful to carry out long term studies and have experiences on using GM products as animal feeding and GM products have to be considered as not the only one solution on the feed and food source problem.

2.4 SUSTAINABLE INTENSIFICATION

To fulfil the world's increasing demand of food we have to intensify the production systems. This does not mean that there is no room for extensive production, but extensive systems require more land and we have limitations in that. Our resources have to be utilized on a proper way; therefore a further intensification of the concentrated farms is necessary. By concentration of animal farms and the advances in technology farmer can have such amount of information, which cannot be handled manually. This needs a special information intensive management system so called precision livestock farming. Precision livestock farming is an integrated approach of animal production aiming to improve the efficiency of use of resources, as well as to enhance animal health and welfare, and thus contributes to sustainable animal production systems. It adopts research and development focusing on technological innovations based on increasingly specialized tools that go beyond human mind power, and are related to the acquisition, access, and processing of the huge number of data (Mollo *et al.*, 2009).

3 PRECISION NUTRITION

A prerequisite for precision livestock farming is to feed the animals in a way that precisely fulfil their nutrient requirement. Considering that 60–70% of the total cost of production attributes to feeding cost therefore the nutrient supply is the most critical element of economic animal farming. Precision livestock farming requires precision nutrition that is by definition an "information intensive nutrition", the actual nutrient supply is adjusted to the real-time data on the animal and its production level. It means not only offering proportional feed rations but supplying continuously changed "tailor made" diets for individual animals. For that reason the animals has to be identified and feed individually according to their actual requirement. But how can be precision nutrition achieved in practice?

According to Sifri (1997) and Pomar *et al.* (2009) the principals of precision nutrition are the followings:

- Use of precise nutrient requirement matrix
- Use of precise ingredient matrix
- Proper use of modifiers and feed processing technologies
- Adjustment of nutrient supply to match requirements of livestock

3.1 USE OF PRECISE NUTRIENT REQUIREMENT MATRIX

It is well known that the actual nutrient requirement depends on animal factors (production level, genetic potential, gender, age and body weight, and health status), environmental factors (ambient temperature and humidity, space allowance, number of stress factors, etc.), as well as on nutritional factors (nutrient composition and ratios, digestibility of nutrients, and level of antinutritive factors). The nutrient requirement can be well established/estimated with mathematical models. An example is given in Fig. 1 showing how digestible lysine requirement of pigs with different genotype changes during the growing and fattening period (adopted from van Milgen *et al*., 2008). The simulated genotypes have the same average daily gain (762 g/d) and daily feed intake (2.24 kg/d); however, the growth curves of them differ gaining 758 vs. 766 g/d in growing (30–65 kg) and 812 vs. 700 g/d in fattening period (65–115 kg), respectively. The digestible lysine requirement certainly differs and the genotypes have to be fed differently according to the dynamics of their growth otherwise the genetic potential cannot be realized and likely the slaughter quality is deteriorated. The advantage of using such models instead of table values is that the model can predict the nutrient requirement at any time point and not only in certain time period and thus the number of phases used during the pig production is a professional decision supported by well predicted data.

In order to be able to adjust the daily nutrition to the actual requirement of livestock the animals has to be checked by real-time body weight control. The body weight can be determined daily by a weighing adapter or by body shape analyser (Banhazi *et al*., 2009). All the factors that influence production and therefore nutrient requirement should be controlled. In precision livestock farming the technology and housing conditions are optimized, however, if it is needed the nutrient supply can also be adjusted according to the changed environmental factors. The health and wellbeing control (behaviour and sound analysis, collecting physiological parameters like deep body temperature, respiratory rates) is also very useful; in case of confirming any disorder the problem can be fixed immediately.

3.2 USE OF PRECISE INGREDIENT MATRIX

The principal of precise formulation is to be able to evaluate properly the nutritional potential of the compound feed. The progression of the characterization of

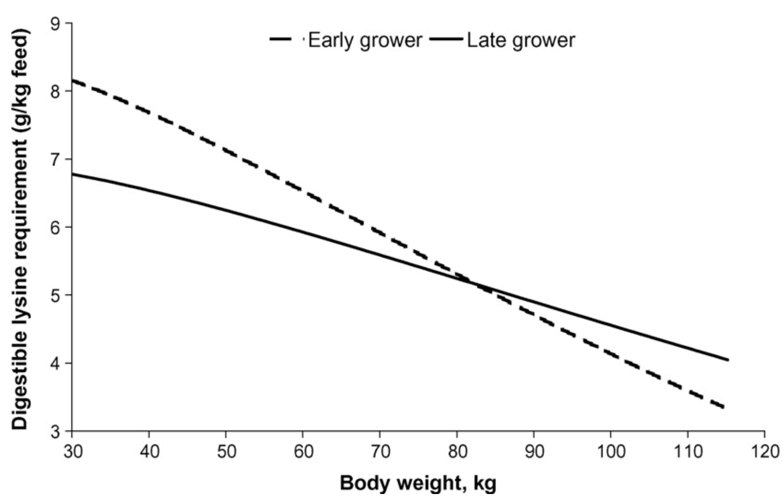

Figure 1: *Simulated digestible lysine requirements for two pigs having same average daily gain and feed intake but different shapes of growth curve (van Milgen et al., 2008)*

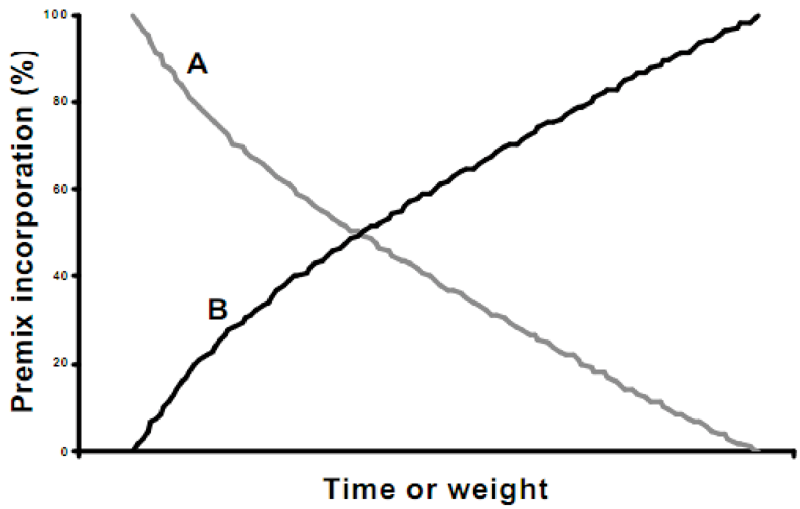

Figure 2: *Example of level of incorporation of the initial (A) and final (B) premixes or feeds in blend feeding systems (Feddes et al., 2000)*

nutritional potential of feedstuffs and animal requirements from a total to a digestible basis, and then to an available or net basis, allows for the formulation of diets with nutrient levels that are closer to the animals' requirements without the use of excessive safety margins (Pomar *et al.*, 2009). It is worth by theory, but protein and even the energy evaluation are different in different countries. In pigs for instance the net energy is the most reliable energy evaluation system particularly if fibre rich feedstuffs – like different by-products – are used in diet formulation. However, there are only a few countries using net energy system in practical swine feeding. The protein evaluation in monogastrics feeding should be based on amino acid content of ingredients with consideration on the ileal digestibility. For the sake of precise diet formulation dietary ileal digestible amino acid content should be expressed in standardized or true digestibility (SID or TID, respectively) rather than apparent digestibility (AID) bases, considering that unlike apparent values both SID and TID content of feedstuffs are additive (Stein *et al.*, 2007). Table values for net energy and dietary SID, TID amino acid of different feedstuffs are available; however, due to the fact that the nutrient content is determined by several conditions (soil, precipitation, cultivation, etc.) there might be big variance in nutrient content of feedstuffs originated from different region or batches. Therefore for precision nutrition national dataset or rather reliable prediction equations are required to be able to determine the bioavailability of energy and amino acids of feedstuffs and compound feeds.

In practice the feeds are usually overformulated by even 7.5% to ensure that no more than 20% of the batches of feed produced are nutritionally inadequate (van Kempen and Simmins, 1997). The safety of margin can be reduced if reliable and actual chemical composition is used in diet formulation. By using prompt assay such as near infrared reflectance spectroscopy (NIRS) the diet formulation is adjusted according to real-time analysis of the feed ingredients to reduce variation in nutrient delivery to the livestock. In addition to determination chemical composition modern scanning NIR spectrophotometers and associated analysis software present the potential for simultaneous prediction of available energy and amino acids in feed ingredients for all livestock (van Barneveld, 2003). In this way the overformulation can be reduced to zero that is desirable from both economic and environmental point of view.

3.3 PROPER USE OF MODIFIERS AND FEED PROCESSING TECHNOLOGIES

Different feed additives are used in compound feed production for purposes of improving the quality and storage life of feed, to improve the animals' performance and health. Feed processing technologies are usually aiming to increase the bioavailability, particularly the digestibility of dietary nutrients and energy. Therefore use of modifiers and processing technologies improve the nutritive value of the compound feed that has to be considered in precision feeding. Fig. 1 shows how the proper/optimal protein supply changes with increasing bioavailability (digestibility and/or availability) of amino acids. According to the linear-plateau concept the relationship between the protein intake and protein deposition is described by a two-phase-graph being composed

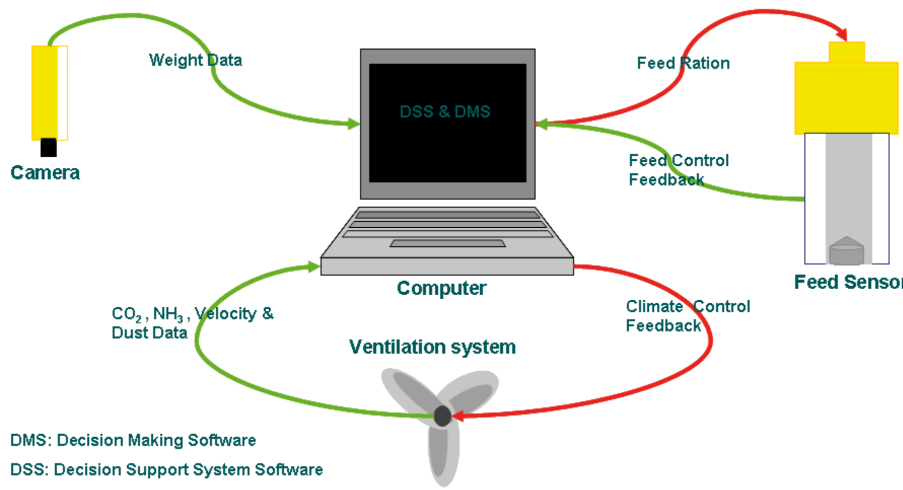

Figure 3: *Schematic representation of an integrated system in pig production (Banhazi et al., 2009)*

of a regression line and a constant phase. The optimal dietary protein intake is at the point when the function reaches first its maximum value (A, B, C). However, exact inflection point depends on the slope of the regression line phase that is certainly determined by the bioavailability of amino acids. The impact of the modifiers therefore should be quantify in order to evaluate precisely the nutritional potential of feed ingredients and thus to avoid overformulation of the diets.

3.4 ADJUSTMENT OF NUTRIENT SUPPLY TO MATCH REQUIREMENTS OF LIVESTOCK

Due to individual variance the nutrient supply that is fulfil the requirement of the maximal growth of a herd is not exactly the optimum for each individual animal within the herd. Hauschild *et al.* (2010) showed that supplying a feed with Lys:NE ratio according to the arithmetic mean of the requirement of pigs is insufficient for the maximal growth of the herd. The growth response reached its maximum when 82% of the animals were fed above their requirement. Actually the differences in individual nutrient requirement increase with the degree of heterogeneity of the population, which is determined by genetic, environmental or management factors (Pomar *et al.*, 2003). Feeding pigs individually according to genetics, gender and actual feed intake and growth patterns can help to simplify the estimation of nutrient requirements (Pomar *et al.*, 2009). In this way the homogeneity of the herd is definitely be under the level of group-fed livestock.

Special individual feeders are available (Feddes *et al.*, 2000; Bánházi *et al.*, 2009, Pomar *et al.*, 2009) driven by computerized data process to provide a "tailor made" diet for each animals. The intelligent system use different pre-mixed feeds to adjust the nutrient supply to the actually fed animal. Considering that the optimal nutrient concentration related to dietary energy content progressively decrease (NRC, 1998) the feeds have to be mixed with a non-linear algorithms (Fig. 2).

Such a system allows a daily adjusted feeding pattern for individual animal, therefore the oversupply attributed to phase feeding can be avoided. In this way the excess nutrients are reduced to zero and the efficiency of production is maximal (Pomar *et al.*, 2011). Fig. 3 represents the integrated management system for pig production in which all the data are collected by the computer and processed with a Decision Making System. The suggested system integration approach would also mean that where it is possible the utilization of existing hardware and software components/products need to be considered. If system components are independently developed and the components compete with existing products; it is likely that precision nutrition and livestock farming (PN&LF) developments and implementation on farms will fail (Bánházi *et al.*, 2009).

Determining and offering the optimal nutrient supply for individual animals at any circumstances is very complex in practice. Companies and research groups all over the word are involved with developing commercially sound PN&LF components; however, a few groups have attempted to combine these components into one system, because of the technical/operational difficulties involved. Nonetheless, business opportunities for a PN&LF package development (including the provision of complete systems, expert advice, training, backup analysis and general support) do exist, but very few companies have taken advantage of such opportunities (Bánházi *et al.*, 2009).

4 CONCLUSIONS

It is likely that sustainable intensification of agricultural production will be one of the key issues in the coming years. However, if we could make firm conclusions regarding to the future, it would presume that we have a time machine. Instead of that we can phrase a wish: be the force with us, to give right answers in time to the challenges we are facing with.

5 REFERENCES

Angell A.R., Pirozzi I., de Nys R., Paul N.A. 2012. Feeding Preferences and the Nutritional Value of Tropical Algae for the Abalone Haliotis asinina. PLoS ONE, 7, 6: e38857. doi:10.1371/journal.pone.0038857

Banhazi T., Babinszky L., Halas V., Tscharke M., Lewis B. 2009. Precision nutrition and smart farming developments for sustainable agriculture production. In: Proceedings of the14th International Symposium on Animal Nutrition, Kaposvár, Hungary, October 6, 2009. Kaposvár, University Press. 83–95

Carillo S., Rios V.H., Calvo C., Carranco M.E., Casas M., Pérez-Gil F. 2012. n-3 Fatty acid content in eggs laid by hens fed with marine algae and sardine oil and stored at different times and temperatures. Journal of Applied Phycology, 24: 593–599

Domingo J.L. 2000. Health risks of genetically modified foods: Many opinions but few data. Science, 288: 1748–1749

Ebadi Z. 2009. Study on earthworm production using different agricultural wastes for animal feed. Karaj (Iran). Report No.: 31661. Animal Science Research Institute – ASRI: 60 p.

Ermakova I. 2005. Influence of genetically modified organisms on posterity of rats: preliminary studies. Food Standards Agency.
http://www.food.gov.uk/multimedia/pdfs/acnfp_74_8.pdf (3 Aug. 2012)

Ewen S.W., Pusztai A. 1999. Effect of diets containing genetically modified potatoes expressing Galanthus nivalis lectin on rat small intestine. Lancet, 354: 1353–1354

FAO. 2010. Food and agriculture organization of the United Nations statistical databases.
http://faostat.fao.org/

Farrell D. 2009. Feeding the future. Livestock Research for Rural Development, Volume 21, Article #219.
http://www.lrrd.org/lrrd21/12/farr21219.htm (3 Aug. 2012)

Feddes J.J.R., Ouellette C.A., Leonard J.J. 2000. A system for providing protein for pigs in intermediately sized grower/finisher barns. Canadian Agricultural Engineering, 42: 209–213

Hauschild L., Pomar C., Lovatto P.A. 2010. Systematic comparison of the empirical and factorial methods used to estimate the nutrient requirements of growing pigs. Animal, 4, 5: 714–723

Jongbloed A.W., Poulsen H.D., Dourmad J.Y., van der Peet-Schwering C.M.C. 1999. Environmental and legislative aspects of pig production in The Netherlands, France and Denmark. Livestock Production Science, 58: 243–249

Mollo M.N., Vendrametto O., Okano M.T. 2009. Precision Livestock Tools to Improve Products and Processes in Broiler Production: A Review. Brazilian Journal of Poultry Science, 11, 4: 211–218

NRC 1998. Nutrient Requirements of Swine. 10th ed. National Academy Press, Washington, DC, USA

Pomar C., Kyriazakis I., Emmans G.C., Knap P.W. 2003. Modeling stochasticity: dealing with populations rather than individual pigs. Journal of Animal Science, 81: 178–186

Pomar C., Hauschild L., Zhang G.H., Pomar J., Lovatto P.A. 2009. Applying precision feeding techniques in growing-finishing pig operations. Revista Brasileira de Zootecnia, 38: 226–237.
http://www.scielo.br/pdf/rbz/v38nspe/v38nspea23.pdf

Pomar C., Hauschild L., Zhang G.H., Pomar J., Lovatto P.A. 2011. Precision feeding can significantly reduce feeding cost and nutrient excretion in growing animals. In: Modelling nutrient digestion and utilisation in farm animals Sauvant D. van Milgen J., Faverdin P., Friggens N. (eds.). Wageningen Academic Publishers: 327–334

Sifri M. 1997. Precision nutrition for poultry. Journal of Applied Poultry Research, 6, 4: 461

Stein H.H., Se`ve B., Fuller M.F., Moughan P.G., de Lange C.F.M. 2007. Invited review: Amino acid bioavailability and digestibility in pig feed ingredients: Terminology and application. Journal of Animal Science, 85: 172–180

Swann M.M., Baxter K.L., Field H.I. 1969. Report of the Joint Committee on the Use of Antibiotics in Animal Husbandry and Veterinary Medicine. Place of the publisher, HMSO

Toral P.G., Belenguer A., Shingfield K.J., Hervas G., Toivonen V., Frutos P. 2012. Fatty acid composition and bacterial community changes in the rumen fluid of lactating sheep fed sunflower oil plus incremental levels of marine algae. Journal of Dairy Science, 95,2: 794–806

van Barneveld R.J. 2003. Prospects for predicting feed quality for monogastrics by near infrared spectroscopy pre-delivery.
http://www.cdesign.com.au/proceedings_abts2003/papers/129vanBarneveld.pdf (3 Aug. 2012)

van Kempen T., Simmins T.O. 1997. Near-Infrared Reflectance Spectroscopy in Precision Feed Formulation. Journal of Applied Poultry Resesearch, 6,4: 471–477

van Milgen J., Valancogne A., Dubois S., Dourmad J.Y., Sève B., Noblet J. 2008. InraPorc: A model and decision support tool for the nutrition of growing pigs. *Animal Feed Science and Technology*, 143: 387–405