Nonruminant Nutrition
An Update on Modeling Pig Growth

690 Pig growth models: Past and present. J. L. Black*, *John L. Black Consulting, Warrimoo, Australia*.

The primary aim of commercial animal production is to maximize profit while maintaining the health and welfare of stock. The net financial return from an enterprise depends on the interactions between many factors including the genotype of animals, diets, climate, stocking arrangements, disease, prices paid for products and costs of feed, breeding stock, capital, labor and other resources. Although there has been much research into these factors, the complexity of the interactions makes it virtually impossible for the human mind to assess accurately the consequences of alternative management strategies on either the efficiency of production or long-term profitability of an enterprise. By transforming the concepts and knowledge into mathematical equations and integrating them into computer programs using simulation-modeling techniques, this store of information can be applied directly to the management of commercial units. Models can be constructed in different ways and represent biological functions at different levels. For example, models applied to the pig industry have been static or dynamic, deterministic or stochastic, empirical or mechanistic. The first growth models applied to pigs in the 1950's and 1960's were static models representing factorial assessments of requirements for energy and protein based on empirical equations. However, by the 1970's, dynamic models were developed to varying complexity involving both empirical and biochemical-physiological representation of animal functions. The sophistication of these models has changed little over the last three decades, but their impact on the pig industry has been marked in some countries. For example, in Australia the AUSPIG model is now used in the management of more than half the country's pigs. The model is used most commonly for improving the formulation of diets to meet the nutrient requirements of individual pig groups by accounting for their genotype and rearing environment. It is used also to identify when climatic conditions limit productivity, excessive feed waste, effluent output, optimize slaughter weights and packers, assist in litigation, set research priority and many other areas.

Key Words: Model, Pig, Present

691 Partitioning of energy intake to heat, protein and fat in growing pigs. J. van Milgen* and J. Noblet, *INRA-UMRVP, St-Gilles, France*.

Modelling aspects of energy metabolism in growing pigs involves establishing rules on the partitioning of dietary energy between protein deposition (PD), lipid deposition (LD) and heat production (HP) at a given point in time as well as the changes that occur during growth. Growing pigs rarely retain more that 50% of the ME intake and the remainder is lost as heat. Part of the heat loss is due to the heat increment, which includes the transformation of dietary nutrients to PD and LD and to the associated energy (ATP) cost. Consequently, different nutrients are used with different efficiencies and (due to the ATP cost), PD is energetically less efficient than LD. Different modelling approaches have been adopted to represent partitioning of energy between PD and LD (e.g., by assuming minimum ratios between LD/PD, marginal LD/PD, or lipid and protein mass, and existence of an upper limit to PD). Most of the HP is associated with biophysical processes (e.g., maintenance, physical activity, thermoregulation) requiring ATP, which are not directly related to PD and LD. As it is virtually impossible to obtain direct estimates of these requirements, indirect methods have to be used. For example, the cost of maintenance may be estimated by measuring the fasting HP. Estimates of the fasting HP range from 700 to 800 kJ (kg BW)$^{-0.60}$ d^{-1}, which corresponds to 50-60% of the total HP. Also HP associated with physical activity is an important component of HP (15%), but can be rather variable between individual animals. Feed intake in non-producing, mature mammals theoretically equals the maintenance energy requirements. This implies that, while maturing, maintenance will become an increasingly important component of energy intake. In addition, while maturing, a decreasing fraction of the energy intake above maintenance is used for PD. The result is that PD typically reaches a maximum at 60-80 kg in growing pigs and declines thereafter. In contrast, with ageing, an increasing fraction of the available energy is used for LD and maximum LD may not be reached before slaughter (110-130 kg). In modelling, this has been represented by assuming that the above-mentioned energy partitioning rules (e.g., minimum LD/PD ratio, upper limit to PD) change with body weight and(or) age.

Key Words: Growing pigs, Models, Energy partitioning

692 The partitioning of dietary amino acid intake — a modelling perspective. Paul J Moughan*, *Institute of Food, Nutrition and Human Health, Massey University*.

In developing a mathematical model to allow prediction of amino acid uptake and partitioning in the growing mammal, the simulation of amino acid metabolism is of particular importance, as the predicted rate of protein deposition has a disproportionate influence on predicted body mass. In reality, the absorption and metabolism of amino acids in mammals is complex and highly integrated with continuous flux within and between body cells. To model amino acid transactions, however, it is required to develop a simplified construct of metabolism describing discrete physiological and metabolic processes. In the construct discussed here a distinction is made between maintenance processes and those associated with growth. Growth is viewed as a function of nutrient deposition and support costs directly related to nutrient deposition. Several processes are emphasised and discussed: food and amino acid intake; amino acid absorption, amino acid losses at maintenance, net protein deposition, inevitable amino acid catabolism, gut endogenous amino acid loss correlated with food intake, the turnover of body protein associated with new protein synthesis, the synthesis of non-amino acid non-protein nitrogen containing compounds and preferential amino acid catabolism.

Key Words: Model, Simulation, Protein

693 Update on pig growth modeling: from chemical to physical body composition. C.F.M. de Lange*[1], P.C.H. Morel[2], and S.H. Birkett[1], [1]*University of Guelph, Canada*, [2]*Massey University, New Zealand*.

Body lipid (L) and body protein mass (P) are key state variables in pig growth models. For predicting growth responses and carcass characteristics, P and L are related quantitatively to physical body composition. The main chemical constituents in the empty body (EB) are water (Wa), L, P and ash (A). Within pig genotypes, Wa is independent of L and closely related to P, e.g. Wa = a x P^b. The parameter a ranges between 4.9 and 5.4 and appears to vary with pig genotype. The parameter b is remarkably constant across pig types, at .855, and represents changes in distribution of P over various body pools with increasing EBW and differences in Wa to P ratios among body pools. The A to P ratio is about .20 and has little impact on estimates of EBW. Gut fill, the difference between live body weight (LBW) and EBW, ranges between .03 and .10 of LBW; it varies with LBW, feeding level, diet characteristics and time off-feed. The distribution of P and L over the main physical body components (dissectible muscle and fat, viscera, blood, bone, integument) varies considerably between groups of pigs and appears influenced by EBW, pig genotype, thermal environment, feeding level and diet characteristics. Except for extreme pig genotypes, the distribution of lean over the main carcass cuts is relatively constant. Little is know about factors contributing to observed variation in the distribution of L over body fat depots. Representing dynamic effects of animal and external factors on sizes of physical body components is an apparent weakness in pig growth models. This is further complicated by inconsistencies in defining some of the physical body components, and dissectible lean tissue in particular. Improved accuracy in representing physical body composition will provide more insight on manipulation of carcass value and efficiencies of converting diet nutrients into pork products.

Key Words: Pigs, Growth modelling, Body composition

694 Characterization of pig genotypes. PW Knap*[1], R Roehe[2], K Kolstad[3], C Pomar[4], and P Luiting[1], [1]*PIC International Group, Schleswig, Germany,* [2]*Christian-Albrechts University, Kiel, Germany,* [3]*Akvaforsk and Agricultural University, Aas, Norway,* [4]*Agriculture and Agri-Food Canada, Lennoxville, Canada.*

Simulation models for growing pigs are driven by descriptors of the pig's growth potential and of its environment, predicting growth from the interaction of both. Growth potential parameters relate to resource intake and its partitioning to maintenance, protein (P) deposition (PD) and lipid (L) deposition (LD), and quantify the pig's genotype (breed etc.). Simulation of a particular pig requires characterization of its genetic potential, in terms of the associated model parameters. This requires (i) a concise set of model parameters that fully describe the potential, (ii) real-life measurement of resource input and partitioning in a genotype, (iii) using those measurements to quantify those parameters for that genotype. (i) Resource partitioning is commonly covered with potential PD, required LD and maintenance requirement (MEm). The first two features often require three model parameters; MEm is here restricted to a neutral environment without additional coping functions (which would require extra parameters). Nutrient intake is most usefully modelled as resulting from nutrient requirements (for PD, LD, MEm) and constraints to physical uptake, either external (feed, climate, health, etc) or genetic (requiring an extra parameter). (ii) Resource intake/partitioning observations must reflect growth potential; hence environmental load must be minimized. Repeatedly measuring whole-body P and L and ad libitum ME intake over a wide enough maturity range (eg. 10-175 kg BW) requires serial slaughter trials with chemical analysis, or X-ray or isotope dilution techniques which allow for longitudinal studies and quantification of between-animal variation next to mean levels. (iii) Model parameters can be estimated by fitting observations to a body protein/lipid growth function. MEm comes out as the remainder of the ME budget, given valid assumptions about PD/LD efficiency. Alternatively, observed feed intake, growth rate and body composition can be fitted to their simulations by calibrating the model parameters. This "inverted modelling" avoids measurement of P and L but requires many observations per animal and an iterative routine to match resource requirements to resource allowance.

Key Words: Growth, Simulation, Genotype

695 Modelling stochasticity: dealing with populations rather than individual pigs. C. Pomar*[1], P. W. Knap[2], I. Kyriazakis[3], and G. C. Emmans[3], [1]*Agriculture and Agri-Food Canada, Lennoxville, Quebec, Canada,* [2]*PIC International Group, Schleswig, Germany,* [3]*Scottish Agricultural College, Edinburgh, UK.*

Pig production efficiency results from the responses of individual animals. However, it is usual to interpret experimental results on the basis of mean animal responses with little emphasis given to the variation around the means. Animals with different performance potentials may respond differently to treatments, which makes it difficult to translate average population responses into either individual animal responses or across populations having different variation between animals. Nutritional theories that form the basis of current models are all at the level of the individual animal. The problem of how properly to integrate across individuals to obtain population predictions is rarely addressed. To illustrate the impact of between-animal variation on population responses to dietary treatments, we use a comprehensive pig growth model that predicts voluntary feed intake from potential protein deposition and the desired lipid retention. The genetic growth potential of individual animals is defined in terms of the growth rate parameter, protein weight at maturity and the ratio of body lipid to protein at maturity. The model was made stochastic by simulating variation and covariation in these genetic parameters. The population responses to increasing levels of dietary protein and energy intake are interpreted based on the individual biological phenomena represented within the model. Variation originated from within the individual animal as growth potentials and nutrient requirements evolves over time and from their variable genetic potentials for growth. The effect of increasing the between-animal genetic variation of the simulated population on feed intake, ADG and protein and lipid deposition was also simulated. Finally, it is shown that the optimal levels of intake will differ between population with different degrees of genetic variation.

Key Words: Genetic variation, Growth, Simulation models

696 Pig growth models: Future. J. L. Black*, *John L. Black Consulting, Warrimoo, Australia.*

Current pig growth models represent the biology controlling the utilization of energy, amino acids and major minerals with a high degree of accuracy when feed intake and the growth characteristics of the pig genotype are known. Many of the determinants of voluntary feed intake are also well understood and intake is often predicted with reasonable accuracy. Further research is needed to understand better the characteristics of cereal grains and other dietary ingredients that effect the site of feed digestion, passage through the digestive tract, physical limits to gut capacity and other factors causing the wide variation seen frequently between apparently similar diets in voluntary intake. Current pig models do not predict well the effects of stress and disease encountered by pigs reared in commercial environments. However, considerable advances have been made in recent years in understanding the physiological mechanisms associated with stress and disease and these concepts are now being incorporated into some pig growth models. Pig models that predict accurately animal performance and carcass characteristics are, by themselves, unlikely to be adopted widely by industry. The models need to be integrated with least-cost feed formulation packages and resource optimization software that will allow enterprise profitability to be predicted with high accuracy. Another limitation to the widespread use of models within the pig industry is the time and effort required to collect the information needed as inputs to the models and to record animal performance for verifying the predictions. A major effort is needed to enable the industry to adopt electronic methods of data capture and the automatic separation of stock to reduce the cost of applying the models on farms. Finally, the markets for decision support software within the pig industry are small relative to the costs of development and servicing the products. Consequently, ongoing industry funds appear necessary to enable the successful and widespread adoption of models across the pig industry.

Key Words: Model, Pig, Future

Sheep Species
Sheep Production in China
The Importance of Small Ruminants for Managing Vegetation

697 Sheep genetic resources in northwest China. M. A. Brown*[1], Jianping Wu[2], Yuzhu Luo[2], and S. Soderstrom[3], [1]*USDA-ARS, Grazinglands Research Laboratory, El Reno, OK,* [2]*Gansu Agricultural University, Lanzhou, Gansu, PRC,* [3]*World Bank, Washington, D.C..*

In China's northwestern pastoral areas, challenges for rural development are especially daunting. Despite the political and strategic importance of the region and progress in agricultural development throughout China, there is a need for further economic growth in this area. This growth is impeded by lack of available production capital for the herders and by grassland degradation. However, animal husbandry will remain the major source of livelihoods and real economic growth in much of northwest China in the foreseeable future, since there are major limitations on opportunities for non-farm enterprises. The government is placing a major emphasis on sheep breeding in the pastoral areas since the climate is particularly suited to fine wool and mutton production. Since the 1950's, extensive effort has gone into developing breeds of fine-wool sheep, based on the introduction of Merino breeds. However, despite this active breeding program, about 60 percent of the national flock of 127,350,000 sheep are still local coarse-wool sheep. Much of the fine-wool breed improvement was conducted on State Farms, where most of the better quality fine-wool sheep are now found. Still, average grease fleece production per sheep is about 2 kg, compared with more than 4 kg in the U.S., and the clean wool yield is 40-50 percent compared with nearly 63 percent in the U.S. Wool contamination is a major problem and the inherent environmental characteristics of the semi-arid pastoral areas contribute to the low yields. The fine wool that