Genetic and individual variabilities of digestion parameters in pigs and poultry

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genesisfaraday

defra
Department for Environment Food and Rural Affairs

Workshop on the potential of livestock genetics, genomics and breeding to reduce methane and N emissions from livestock systems

Thursday, November 8th 2007
Moredun Research Institute, Scotland

The aim of the event is to explore the potential for livestock breeding, genetics and genomics to contribute reducing methane and Nitrogen compounds from the most relevant livestock systems in the UK. With this purpose, we will explore several topics that are likely to play an important role in the emissions and which should be well understood and targeted to mitigate emissions and to adapt our livestock systems to the future environments.

Programme

10:00 Registration and coffee
10:30 Welcome message *by Chris Warkup (Genesis Faraday, UK)*
10:45 SESSION 1 – *Chair: David Garwes*

- **Assessing the effect of genetic improvement on enteric and nitrogenous emissions using LCA modeling** – *Adrian Williams (Cranfield University, UK)*
- **Broader breeding goals – options to mitigate emissions from farming systems** - *Eileen Wall (SAC, UK)*
- **Requirements of future production systems and the consequences for current breeding goals** - *Roger Street (UKCIP, UK)*
- **Discussion**

12:40 Lunch
13:30 SESSION 2 – *Chair: Phil Garnsworthy*

- **Genetic variation in the host component of rumen function** - *Robert Herd (DPI, Australia)*
- **Genetic and individual variabilities of digestion parameters in pigs and poultry** - *Bernard Carre (INRA, France)*
- **Genetic variation in post-absorption utilization of nutrients** - *Brian Bequette (University of Maryland, USA)*

14:45 Coffee break
15:10

- **Impacts of Selection for Disease Resistance** - *Steve Bishop (Roslin Institute,UK)*
- **Synergy between developments in plant and livestock breeding maximizing the overall benefit** - *Mike Theodorou (IGER, UK)*
- **Biotechnology and reduction of emissions** – *Kevin Wells (University of Missouri, USA)*
- **Discussion**

16:55 Closing remarks of the symposium - *Chris Haley (Roslin Institute, UK)*

Genetic and individual variabilities of digestion parameters in pigs and poultry

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Introduction

An animal nutritional system can be defined as a flow of compounds with inputs and outputs. Outputs can be separated into a part which is strictly useful to animal, and a residual part which is considered as wastage. So, it is possible to express this system in terms of efficiency. Concerning the organic matter flow, the useful part of outputs is represented by 1- the respiratory CO_2 and H_2O losses resulting from the heat production for body temperature maintenance, and 2- the production of organic compounds as growth or reproductive components. The wastage part of organic matter outputs is represented by 1- the respiratory CO_2 and H_2O losses resulting from what is called "heat increment", 2- the faeces and urine organic components and 3- the bacterial digestion gases (CO_2, CH_4, H_2).

The rates of useful output from organic matter inputs have been extensively studied in animals, using the combustion gross energy as an expression of organic matter. Such yields are called rates of "net energy". In practice, the net energy rates are about 60% and 55% for pigs and poultry, respectively (Noblet *et al.*, 1989; Carré, 2001). So, energy wastage rates for these species are about 40% and 45%, respectively. Under practical conditions, energy wastage coming from digestive dry matter losses represent about 17% and 25% of the gross energy inputs in pigs and poultry, respectively. Digestive gas losses represent less than 1% of the energy inputs.

The improved net energy rate in pigs compared with poultry mainly comes from the fact that pigs, in contrast with poultry, recover a noticeable part of their dietary energy through bacterial digestion in the colon.

The colon of poultry is very short and does not show bacterial digestion. In poultry, the only digestive parts devoted to bacterial digestions are caeca. However, caeca of poultry are small, their functionality in growing animals is low, and only liquids and very small particles can enter them. Thus, the extent of bacterial digestion in chickens is low (no more than 5% of total digestions), while it represents up to 20% of total digestions in pigs (Noblet *et al.*, 1989).

Concerning nitrogen, rates of body deposition from feeding are usually about 50% in growing pigs and chickens. Nitrogen wastage due to digestion represents about 20% of nitrogen inputs. The remaining 30% wastage comes from urinary losses.

Variabilities in energy and nitrogen efficiencies originating from diets, animals and environments could be very high in pigs and poultry, especially that coming from diets. However, practical diet formulations are done in order to expect low efficiency variations between various diets. Environment is also more and more precisely controlled in order to avoid efficiency variabilities.

Thus, at present, the main sources of variation in energy and nitrogen efficiencies are those associated with animals. Variations coming from animals could even be higher if diet formulation and environment were more variable. In fact, diet and environment parameters are often set taking into account the interactions between the individual factor (or the genetic factor) and the diet or environment factors. Thus, a greater stability in animal responses not only would improve efficiency predictions, but also would give more opportunities for variations in diet formulations and environment conditions.

Efficiency variations among animals may come from post-absorption metabolisms or from digestive functions. We will focus here on digestive functions.

Individual or genetic variabilities in digestion efficiencies

Individual digestion efficiencies are usually measured in pigs and poultry using individual cages set for the individual measurements of feed inputs and digestive outputs. An experimental plant for such measurements may include about 20 individual cages for pigs. For poultry, this number can reach 300. Thus, poultry seem to be well adapted to genetic experiments on digestion efficiency, as those require large number of animals. It may be noticed that such methods do not require the animals to be killed, which facilitates genetic selection.

However, until now, only two genetic selection experiments on digestion efficiency have been performed in poultry, with an experiment conducted in France on the efficiency of gross energy digestion (Mignon-Grasteau *et al*., 2004), and another one in US on the efficiency of phytic acid digestion (Zhang *et al*., 2005). The parameter that was used in the former experiment was the apparent metabolisable energy value corrected to 0 nitrogen retention (AMEn) (Mignon-Grasteau *et al*., 2004). This correction allows the metabolism factor (uric acid losses) to be removed from the sources of variation. Thus, the AMEn variations come only from digestion efficiency variations.

It is probable that such experiments are very few because they are very heavy. Heritability of phytic acid digestion was observed to be very low (Zhang *et al*., 2005). In contrast, heritabilities were high (0.33-0.47) for energy, lipid, starch and protein digestion efficiencies in 3 w old chickens fed on a wheat diet (Mignon-Grasteau *et al*., 2004). These latter genetic effects were only observed during growth and disappeared from 8 w of age (Carré *et al*., 2005). Gizzard functions were probably involved in this divergence, as relative weights of gizzard were observed to be bigger in D^+ (good digesters) than in D^- (bad digesters) birds (Péron *et al*., 2006; Rougière *et al*., 2007). Moreover, a stimulation of gizzard growth by coarse particles resulted in digestibility improvements in D^- and no effect in D^+ birds (Rougière *et al*., 2007).

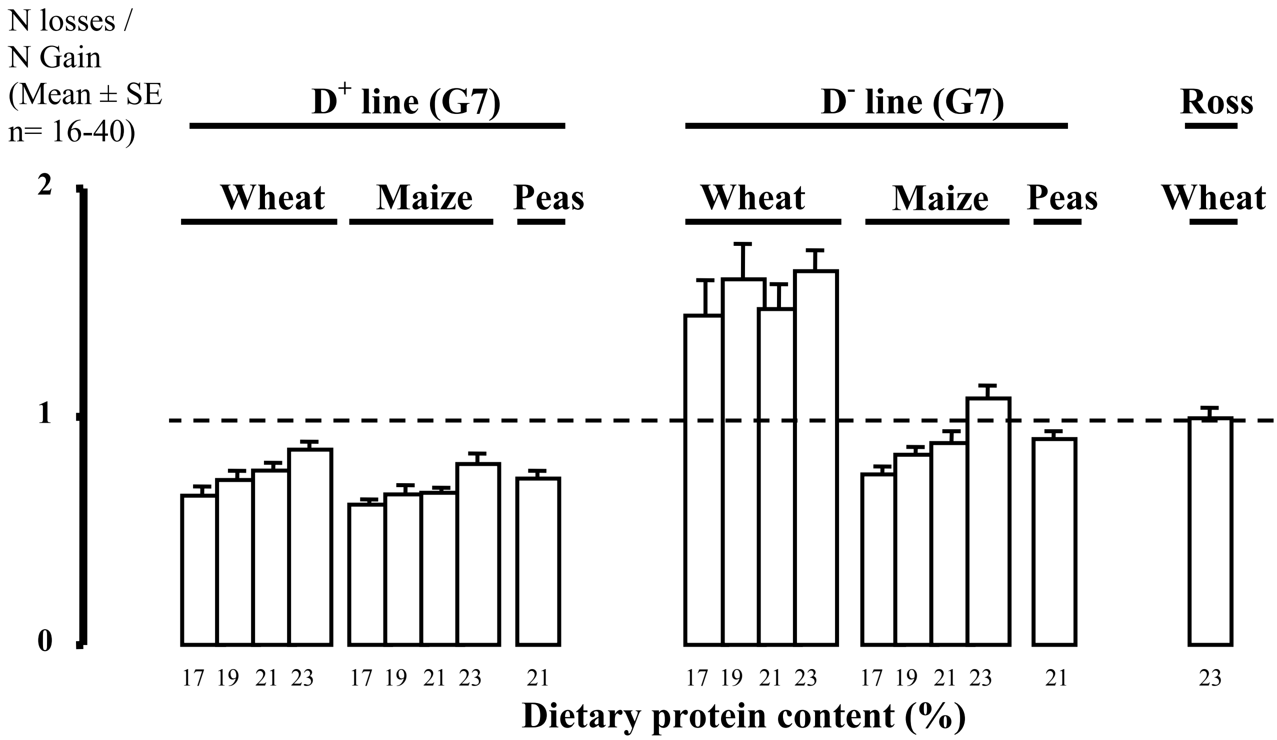
The D^+ birds showed much lower excreta losses than D^- ones. This was especially observed for nitrogen in birds fed on a wheat diet (Figure 1). In this experiment (Figure 1), protein digestion rate was not the main factor responsible for these responses, as the genetic divergence in protein digestion rate between lines is not so strong. With a wheat diet, genetic divergence is more pronounced on AMEn than on protein digestion (Mignon-Grasteau *et al*., 2004). So, this nitrogen over-excretion of D^- fed on a wheat diet (Figure 1) was explained by their high feed intake compensating the low AMEn value of their diet, which resulted in an over-consumption of proteins leading to a nitrogen over-excretion.

Probably no experiment of genetic selection on digestion efficiency has been conducted in pigs. However, several studies showed in pigs that digestion efficiencies may depend on the genetic origin of animals (Varel *et al*. 1988; Février *et al*., 1988; Morales *et al*., 2002ab, 2003; Yen *et al*., 2004; Hennig *et al*., 2004). Moreover, a highly significant effect of individuals on fibre digestibity was observed in pigs (Chwalibog *et al*., 1988)

Genetic effects on digestion efficiencies as affected by interactions with feed composition

Studies of D^+ and D^- chickens (Mignon-Grasteau *et al.*, 2004) revealed pronounced feed x genetics interactions (Carré *et al.*, 2005; Péron *et al.*, 2006; Garcia *et al.*, 2007; Rougière *et al.*, 2007). For instance, differences between D^+ and D^- lines were more pronounced on wheat than on maize diet (Carré *et al.*, 2005, 2007a). Interactions that involve D^+ and D^- birds probably come from the fact that D^- birds reach the limits of the digestion physiology, while D^+ birds are far from these limits. So, it can be expected that many factors can induce interactions with these lines. For instance, a soft wheat cultivar compared to a hard one resulted in an AMEn improvement in D^+, not in D^- birds (Péron *et al.*, 2006), and antibiotics were shown to result in 14% AMEn improvement in D^- birds against only 2.6% in D^+ birds (Garcia *et al.*, 2007). Coarse particles were shown to result in digestion improvements in D^- birds, not in D^+ ones (Rougière *et al.*, 2007), which suggests that a fine grinding process reducing accessibility problems could improve digestibilities in D^+ birds, while this could be negative in D^- birds.

Figure 1. N losses relative to N gain in 3 w old chickens fed pelleted diets : effects of genetic origin of birds (D^+, D^- "Digestion" lines, or Ross), starch sources (wheat, maize or peas) and dietary protein levels (17, 19, 21 or 23%).



<u>Statistical analysis</u>

Genetics	***
Starch source	***
Protein level	***
Line x Starch source	***

Generally speaking, it seems that AMEn values in D^+ birds are very stable and rather close to the values predicted from diet composition. In contrast, AMEn values in D^- birds may be affected by many unexpected factors and, thus, seem very volatile.

As individual variations of wheat diet AMEn values in growing chicks are a major factor associated with individual feed efficiency variations, such diets would be efficient for selecting high digestibilities on the basis of a selection programme applied on feed efficiency (Carré et al., 2007b).

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