Recent Advances in Animal Nutrition 2013

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CONTEXT

PREFACE

The 45th University of Nottingham Feed Conference was held at the School of Biosciences, Sutton Bonington Campus, 25th – 26th June 2013. The Conference was divided into sessions that covered areas of topical interest to the animal feed industry. These sessions were Ruminants, General Issues, and Non-ruminants.

The Ruminant section starts with a paper reviewing the implications of feeding low protein diets to dairy cows in order to reduce nitrogen excretion. The second and third papers report recent studies of mineral nutrition of dairy cows, particularly copper, including levels found on farms, responses to supplementation and implications for cow health. The fourth paper reviews impacts of pre-calving nutrition on health of dairy cows and their offspring. The fifth paper gives preliminary findings of a long-term study comparing dairy systems based either on home-grown feeds or by-products. The sixth paper describes prediction models for production responses of dairy cows fed on silage-based diets.

The General section starts with a paper predicting the influence of global trends in milk and feed prices on dairy and feed businesses. The second paper describes a comprehensive tool for calculating the carbon footprint of animal feeds. The third paper is a timely update on EU legislation affecting the animal feed industry.

The non-ruminant section consists of six papers concerned with environmental impact and animal health. The first paper uses a life-cycle approach to examine the potential for reducing environmental impact of broiler production. The second paper reports studies to evaluate home-grown legumes as alternatives to soya in pig diets. The third paper reviews knowledge of gut health and immunity in pigs. The fourth paper looks at how diet can influence gut health. The fifth paper reviews the effects of pig health on production efficiency. The final paper reviews the nutritional quality of soya for non-ruminants.

We would like to thank all speakers for their presentations and written papers, which have maintained the high standards and international standing of the Nottingham Feed Conference. We are grateful to all those members of the feed industry who provided suggestions and assistance in developing the conference programme. We would also like to acknowledge the input of those who helped us to chair sessions (Mike Wilkinson and Tim Parr) and the administrative (managed by Kathy Lawson and Sheila Northover), catering and support staff who ensure the smooth running of the conference. We would like to thank our sponsors (listed on next page). Finally we would like to thank the delegates who made valuable contributions both to the discussion sessions and the general atmosphere of the meeting.

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300-1000 mg/kg DM, well above the maximum concentration of 207 mg/kg DM reported on UK dairy farms by Sinclair and Atkins (2013). Feeding too low a level of Zn can reduce animal performance and decrease immune response to infection. For example, in the study of Cope, Mackenzie, Wilde and Sinclair (2009), feeding Zn at 63 mg/kg DM reduced somatic cell count compared to cows fed 47 mg/kg DM (Table 4). Feeding Zn in an organic form compared to inorganic (ZnO) at the higher level also increased milk yield, an effect that was related to a more persistent milk yield that became evident after 6 weeks of feeding. Feeding Zn above requirements can increase diet cost and potentially resulting in a build-up in the environment. The trace elements Zn and Cu in particular accumulate in soil over time, although their solubility is often low and may not be readily available to plants and foraging animals (Brock, Ketterings and McBride, 2006).

For Cu, Tables 1 and 2 indicate that cows were on average being fed 154 above requirements in early lactation and 87% above requirements in late lactation. Herds that had high concentrations of molybdenum (Mo) in the diet (which would be expected to reduce the availability of Cu), were feeding low concentrations of Cu, whereas those with low dietary concentrations of Mo were often feeding high amounts of Cu (Fig 1). It would therefore have been of benefit for the herds involved to have determined forage mineral content before considering levels of supplementation. EU Regulation 1831/2003 on additives in animal feed sets the maximum permitted level of Cu in cattle feed at 35 mg/kg (ppm), which at 88% dry matter (DM) equates to 40 mg/kg on a dry matter basis. Of the 50 farms sampled in early lactation by Sinclair and Atkins (2013), 6 were feeding Cu above this limit, with 32 feeding above the recent industry maximum guideline of 20 mg/kg DM (Advisory Committee on Animal Feed, 2010). All herds were feeding substantially above the nutritional guideline of 11 mg/kg DM (NRC, 2001). Dietary levels were generally lower in later lactation, but there was still 2 farms feeding above the legal limit and 27 feeding above the industry guideline. Even within herds that had organic accreditation, 2

Table 4 Effect of level and form of dietary Zn on performance and health of cows fed diets that contained either 63 or 42 mg Zn/kg DM in an inorganic (ZnO: I) or organic (BioplexZn®: O) form (Cope *et al.*, 2009)

	Treatments				
	63-I	63-O	42-I	42-O	sem
Diet Zn (mg/kg DM)	62.7	63.9	41.8	41.4	
Total DM intake, kg/d	22.8	23.7	23.1	24.0	0.819
Milk yield, kg/d	35.2	37.6	36.0	35.2	0.96
Fat, g/kg	40.7	41.0	41.9	42.0	1.67
Protein, g/kg	33.2	32.4	33.8	33.0	1.04
SCC, log (base e)	3.97	3.93	4.35	4.55	0.430
Milk amyloid A, µg/mL	0.90	0.88	1.21	1.57	0.295

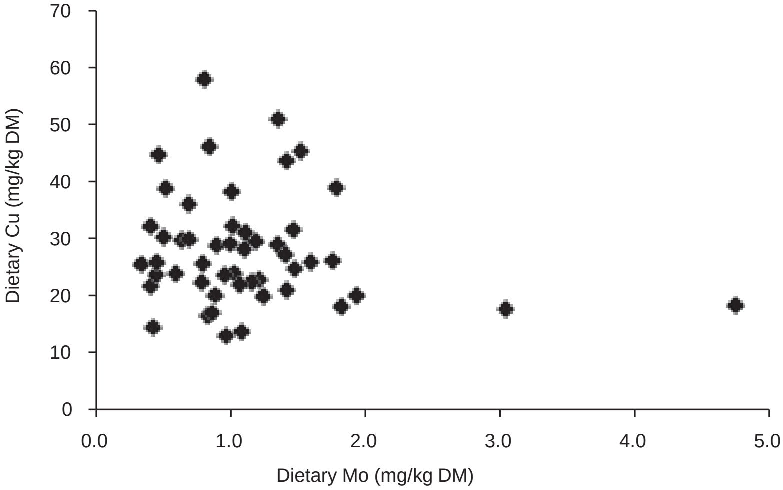

Figure 1. Relationship between dietary Cu and Mo concentrations in diets fed to early lactation on 50 dairy herds in the UK (Sinclair and Atkins, unpublished). Values represent the contribution from the diet, water and supplementary sources, and are expressed on a kg DM intake basis. $y = 30.4 -2.18x$. $P = 0.265$; $R^2 = 0.03$.

were on average (i.e. the mean of the early and late lactation diets) feeding above 20 mg Cu/kg DM.

Dietary requirements and supply of copper

Interest in Cu in dairy cow diets centres around its role as an essential trace element required within numerous key enzymes including cytochrome *c* oxidase, superoxide dismutase (SOD_1), tyrosinase, lysyl oxidase and caeruloplasmin (Suttle, 2010). As a consequence, a deficiency of Cu is related to impairment of growth, reproduction, connective tissue development and pigmentation (McDowell, 1985). A deficiency of Cu can be regarded as either primary, due to a lack of Cu in the diet, or secondary, whereby there is an interaction between Cu and antagonists which reduce its absorption or function (Phillippo, Humphries, Atkinson, Henderson and Garthwaite, 1987). Interactions with zinc, manganese, calcium, and several other transition metals have been reported, although they are generally considered not significant in farm animals (Graham, 1991). The most widely researched antagonists include S, Mo and Fe, and it is generally regarded that secondary deficiency is more common and economically important (Suttle, 2010). Dietary Mo interacts with S in the rumen resulting in production of thiomolybdates (TM; see review of Gould and Kendall, 2011). Thiomolybdates bind with available Cu in the rumen rendering Cu unavailable

Copper

Although acute copper toxicity can occur this tends to be rare as a large quantity of copper is required over a short time period, either by ingestion or injection. Copper toxicity in cattle is usually a chronic biphasic condition similar to that found in sheep, with a period of copper accumulation within the liver (copper loading) followed by a haemolytic crisis, which is usually observed clinically as sudden death. It must be noted that a copper loaded animal will show no clinical sign until a trigger stressor (e.g. change in nutrition, traveling, handling, onset of lactation) is encountered which triggers the haemolytic crisis. Blood copper levels only rise during the haemolytic crisis, but liver copper concentrations increase during the loading phase (Radostits *et al.*, 2007; Underwood and Suttle, 1999).

In the UK there have been a number of reports of cow death diagnosed to be due to copper toxicity over recent years and a recent cull cow liver mineral concentration survey (Holmes-Pavord, Young and Kendall, unpublished data) has shown a varied distribution with 52% of animals above lab-normal range with 34.5 % of animals being considered toxic (according to AHVLA criteria > 8000 µmol/kg DM) in a mixture of dairy and beef culls. Further analysis of these data with exclusion of male cattle and the females split into breeds and breed types has shown that dairy cows generally have increased liver copper loading in comparison to beef cattle (Figures 2 and 3) with approximately 40% in the toxic range for dairy cattle whilst only 15 – 20% of the beef cattle were in the toxic range. Approximately 50% of the beef cattle had liver copper concentrations below the normal range (<1405 µmol/kg DM). In dairy cattle there were more below normal ranges (20% c/w 8%) and less above normal but below toxic ranges (8% c/w 20%) for the other dairy breeds in comparison to the Holstein Friesian breeds. This could be due to farming system with there likely to be a greater proportion of other dairy breeds in extensive and organic systems. Figure 4 shows that there is no significant effect of age on copper accumulation.

Although the maximum permissible level (MPL) for feeding copper is 35 mg/kg (40 mg/kg DM), many rations have been formulated to this level in the first instance resulting in copper accumulation. The guidance recommends formulating to a level of 20 mg/kg DM. However, work at Harper Adams University (Sinclair et al, Personal Communication) has shown 13-14 mg Cu/kg DM to be adequate to maintain performance and reproductive function in pregnant and lactating heifers. In another trial they found that feeding copper at rate of 16 mg Cu /kg DM resulted in increasing liver copper concentrations in heifers. Feeding in excess of the MPL, requires a risk assessment and written veterinary prescription. Although complementary copper sources (e.g. boluses, licks) are not within the MPL the total copper intakes should be calculated.

Regulation 999/2001 laying down rules for the prevention, control and eradication of certain transmissible spongiform encephalopathies (17)

This Regulation applies to the production and placing on the market of live animals and products of animal origin and in certain specific cases to exports. Together with the Animal By-Product (ABP) Regulation (1069/2009) (18) it prevents the use of most animal proteins in feed for food-producing animals.

Commission Regulation 56/2013 (19) amending Annexes I and IV to Regulation 999/2001 to permit the feeding of non-ruminant processed animal protein (PAP) to aquaculture animals (i.e. fish, molluscs and crustaceans) comes into operation from 1 June 2013. The use of bloodmeal and blood protein in feeds for farmed fish has been permitted for some years.

On 8 March 2013, the EU Commission presented a proposal for the lifting of the ban on the use of PAP from poultry origin for pig feeding at a meeting of the Working Group of the SCoFCAH – Section biological safety of the food chain. The outline of the proposal, which is based on Regulation 56/2013, is as follows:-

- Separate production, storage and transport facilities throughout the system i.e. slaughterhouses, renderers, feed mills and onto farm to ensure no intra-species recycling (which is banned under the Animal By-Products Regulation);
- Compound feed manufacturers shall get a special authorisation for using poultry PAPs. They should be either specialised in pig feed production or completely dedicated production lines from storage of poultry PAPs to the storage of pig feed.
- Labelling requirements for:-
  - Poultry PAPs should be labelled as "processed animal protein derived from poultry – shall not be used for the production of feed for farmed animals except pigs, aquaculture animals and fur animals";
  - Compound feed containing poultry PAPs should be labelled as "contains processed animal protein derived from poultry – shall not be fed to farmed animals except pigs, aquaculture animals and fur animals";

The proposal does not cover the feeding of pig PAP to poultry because the European Union Reference Laboratory for Animal Proteins (EURL-AP) has not yet developed a DNA-based test method able to detect very low levels of poultry material that may be present in pig PAP. A diagnostic DNA-based method which is able to detect very low level of pig material that may be present in poultry PAP and compound feed containing PAP could be completed by September 2013;

At the time of writing this paper it is understood that this legislation is unlikely to come into force until the middle of 2014 at the earliest.

model and, as the animal growth and feed intake was assumed to remain unchanged, the only factor affecting the differences in the amount of the nutrients in manure in different feeding scenarios was the nutrient (mainly protein) content of the diets.

Effect of using European protein sources on Global Warming Potential

The results of the LCA model shows that when LUC emissions were calculated by the "best estimate" method, the bean- and pea-based broiler diets reduced the GWP of broiler production by up 12% compared to the soya-based baseline diet (Table 3). Despite the relatively high inclusion of these alternative ingredients, this reduction is rather modest and, when all uncertainties in the calculations are taken into account, it was found that this effect is not statistically significant. No reduction in GWP compared to the baseline was found with the sunflower diets (Table 3).

The exclusion of the LUC emissions from soya ("sustainable soya" scenario) alone had a larger effect on GHG emissions than replacing part of soya with alternative protein sources. For the baseline soya based diets, the "sustainable soya" scenario showed an 18% reduction in GWP compared to the baseline soya diets in the "best estimate" scenario. This demonstrates the large effect of LUC on the greenhouse gas emissions of broiler production. When the "sustainable soya" scenario was applied for all diets (Table 3), the differences in GWP between the alternative protein and the baseline soya diets were only minimal (up to 1% reduction with the bean and pea diets). The reason for these very small differences is that, without the LUC effect, the GHG emissions related to soya production represent a relatively small proportion of the overall GWP of broiler production. Furthermore, as discussed above, beans and peas replaced not only soya in the diets but also part of other ingredients such as the wheat used as an energy source. Therefore, an unwanted consequence was that the wheat had to be replaced with other energy sources, each of which having their own environmental impacts which could be bigger than those of the removed wheat. In general, to maintain the nutrient and energy balance of the alternative diets, higher amounts of pure amino acids and vegetable oil had to be added to alternative diets compared to the original soya diets. Although the amount of these ingredients still remained relatively low, their GHG emissions per unit are high and, as a result, they counteracted the favourable effect of soya reduction.

When the effects of both direct and indirect LUC were taken into account ("top-down" scenario), the GWP of the baseline soya diets was about 5% lower compared to the "best estimate" scenario (Table 3). However, this figure was still about 14% higher than the baseline GWP in the "sustainable soya" scenario showing that, when the LUC-related GHG emissions (either only direct or both direct and indirect) are

Table 3. Global warming potential (GWP, kg CO_2 equivalent, 100 years timescale) per 1000 kg expected edible broiler carcass weight with different diets and different scenarios for land use change (LUC) (Leinonen *et al.* 2013).

Scenario	Baseline (Soya)	Bean	Pea	Sunflower
GWP, "Best estimate"	4360	4000	3850	4390
GWP, "Sustainable soya"	3580	3570	3500	3800
GWP, "Top-down"	4140	4100	4060	4190

taken into account, they alone have a significant contribution to the GWP of broiler production. On the other hand, the differences between the baseline soya based and the alternative diets were small in the "top-down" scenario. For example, the changes in GWP varied from a 2% reduction (extreme pea diet) to a 1% increase (sunflower diet).

In general, the potential to reduce the GWP of livestock production by using European protein sources instead of soya in animal feed seems to be rather limited. Even in the scenario where only the direct land use changes (mainly related to soya production) were taken into account, the reduction was very small and non-significant. In cases where both direct and indirect LUC was included in the analyses, or no LUC was associated with soya production, the potential to reduce GWP was non-existent. The methodological differences in LUC accounting make it difficult to compare the results between different studies, and therefore more research is needed into both improving the estimation of both direct and indirect LUC emissions and establishing the links between changing agricultural activities and rates of LUC across the world. However, despite differences in methods and approach, current results concerning the potential changes in GWP are consistent with other previously published similar studies. For example, Baumgartner *et al.* (2008) also found a rather limited potential of European legumes to reduce the environmental impacts, when used in livestock feed.

Effect of European protein sources on Acidification Potential (AP) and Eutrophication Potential (EP)

Because the different methods for accounting for LUC considered only CO_2 emissions, these methods had no effect on the eutrophication and acidification potentials. The alternative diets based on European protein sources had only a minor effect on the EP (Table 4). Nitrate leaching from the growing of beans and peas is relatively high, due to the surplus nitrogen these crops fix directly from the atmosphere, and this increases their overall EP. However, this effect was partly counterbalanced by the crude protein content of feed being considerably lower in the diets with European protein crops than in the baseline soya diet. This was caused by the high inclusion of

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Known probiotic actions in the pig

Lactobacillus species form a stable microbial population in the piglet intestine from birth until adulthood, making these bacteria a sensible candidate for probiotic investigation. Lactic acid production by lactobacilli decreases the pH in the lumen, thereby maintaining a balanced gut microbiota and enhancing nutrient digestibility (Pieper *et al.*, 2008). Evidence for the probiotic action of *Lactobacillus* species is well-investigated. For instance, pigs fed a combination of *L. murinus*, *L. salivarius*, *L. pentosus*, and *Pediococcus pentosaceous* show reduced incidences of diarrhoea associated with *Salmonella typhimurium* infection, together with reduced faecal Salmonella numbers (Casey *et al.*, 2007). Probiotic-fed animals also show a greater weight gain over the course of the experiment.

Apart from the observed direct effects on health of probiotic *Lactobacillus* species, they are also able to direct the composition of the microbiota. This includes an increase in the number of indigenous *Lactobacilli* in the intestine (Takahashi *et al.*, 2007), as well as the general diversity of the population. Beneficial changes to the microbiota composition induced by Lactobacilli are partly due to short-chain fatty acid production. Increased *Lactobacillus* levels in the gut result in higher lactate production, which is further metabolized to butyrate, acetate, and propionate by lactate-utilizing bacteria. The efficacy of probiotic bacteria is therefore dependent on the composition of indigenous lactate-utilizing bacteria. It is important to consider that probiotics are species- and individual animal-specific, as they are dependent on the indigenous host microbiota. A probiotic strain that is effective for a particular animal species might not be suitable for other host species. As the composition of the intestinal microflora changes with each life stage of the host, specific probiotic strains are suitable for each specific stage in life.

Yeasts are suitable as potential probiotics, as they are highly resistant to inactivation during gastrointestinal passage. *Saccharomyces cerevisiae* ssp. *boulardii* is a non-pathogenic yeast that is rich in enzymes, vitamins, nutrients and co-factors. Generally, yeast strains have a variety of beneficial production responses in piglets (Price *et al.*, 2010; Kiarie *et al.*, 2012; van Heugten *et al.*, 2003; Lessard *et al.*, 2009). For instance, piglets fed *S. cerevisiae* ssp. *boulardii f*or six weeks followed by *Pediococcus acidilactici* for three weeks had improved FCR rate and produced a transitory improvement in the LAB/coliform ratio, together with significantly reduced levels of *E. coli* (Le Bon *et al.*, 2010). *S. cerevisiae* ssp. *boulardii* has positive effects on the gut-associated immune system. These include enhanced secretion of specific IgA and reduced binding of bacterial toxins to epithelial receptors (reviewed in (Bontempo *et al.*, 2006))

Enterococcus is the third-largest genus of lactic acid bacteria (LAB) after the genera *Lactobacillus* and *Streptococcus*. *Enterococcus faecium* is the best studied probiotics in pigs. *E. faecium* is able to decrease piglet mortality, improve growth parameters,

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This book contains the proceedings of the 45th University of Nottingham Feed Conference.

The Ruminant section is concerned with improving efficiency of dairy systems whilst reducing environmental impact. The first chapter reviews effects of low protein diets. The second and third discuss mineral nutrition with particular emphasis on copper supplementation. The fourth reviews impacts of pre-calving nutrition on cow and calf health. The fifth compares systems based on home-grown feeds or by-products. The sixth presents prediction models for milk production responses to nutrition.

The General section starts with a chapter on global trends in feed and milk prices. The second describes the FeedPrint tool for calculating carbon footprint of animal feeds. The third provides an update on legislation affecting the animal feed industry.

The non-ruminant section is concerned with environmental impact and health of pigs and poultry. The first chapter presents life cycle analysis of dietary options in broiler production. The second presents results of trials on peas and beans in pig diets. The third reviews gut health and immunity in piglets. The fourth discusses effects of diet on gut health in pigs. The fifth describes the importance of pig health on production efficiency. The final chapter reviews nutritional quality of soya products for non-ruminants.

All chapters are written by international experts and provide comprehensive analyses of issues alongside practical applications. This book is essential reading for anyone involved in the livestock industry, including nutritionists, feed suppliers, researchers, consultants, animal science students, legislators and veterinary practitioners.

Preface • Low protein diets for dairy cows • Mineral requirements and responses of dairy cows • Mineral supply and health of dairy cows • Pre-calving nutrition and health of cows and calves • Dairy systems based on home-grown or by-products feeds • Prediction of production responses to nutrition in dairy cows • Global trends in feed and milk prices • Carbon footprint of animal feeds • Legislation affecting the animal feed industry • Diet effects on environmental impact of broilers • Peas and beans in pig diets • Mucosal immunity in pigs • Feeding the pig for gut health • Pig health and production efficiency • Soya products for non-ruminants • List of participants • Index

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