Improving resource use in ruminant systems

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Abstract

The objectives of ruminant systems are becoming more diverse with dairy systems becoming more efficiency-driven and intensive within the context of a number of external constraints whilst meat-producing systems are becoming more multi-objective and often more extensive. Whilst this divergence has meant that some nutrition and management strategies have also become different, this has not been universal. Dairy systems require increased precision in the nutritive value of feeds and their combinations and the efficiency with which nutrients are utilized. Meat systems from ruminants often seek to use feed by-products more effectively and utilize alternative feeds. In terms of management strategies, diary systems are developing management strategies which minimize the impact of external constraints, such as environmental legislation, whilst meat systems may seek to alter management to obtain the benefits that can arise from environmental management. However, there are common technological advances that all ruminant systems seek to use. Examples of these are the increase in the understanding of the interaction between nutrition, management and disease, and the role of dietary manipulation in providing animal products to meet consumer demands. In dairy systems, laminitis, and in meat systems, intestinal parasites, are examples where the role of nutrition and management strategies are providing options in the control of disease. The manipulation of conjugated linoleic acids in milk and meat through the diet also has potential. Future opportunities for nutrition and management strategies to improve resource efficiency are indicated.

Introduction

The objective of this paper is to review how resource use in dairy and meat systems involving ruminants can be improved by the application of current knowledge and through future research with particular reference to the role that nutrition may play in this. In most European countries at present the research agenda is set by governments and industry demanding a short lead time of a few years between the conduct of the research and its application. This has lead to an emphasis on applied and developmental research at the expense of more strategic research and there is no sign of a change in direction taking place. This emphasis relates as much to ruminants as to other crop or livestock production systems. This paper, therefore, reflects the current trends in research effort which leads to research on efficiency of production, the interaction of nutrition and disease, and the development of livestock systems which meet broader societal demands. There is also no doubt that ruminant nutrition is regarded as a mature area of research and that funding for the more strategic areas of research on ruminants is only available if it can be linked to an area of research that is more in vogue. For example, nutritional research on ruminants is more likely to be funded if it is linked to research on systems or in relation to genetic improvement. These arguments lead to the conclusion that research on resources use in ruminants has to be seen within the context of current developments in livestock policy within Europe.

Within Europe there is a great diversity in ruminant livestock systems which reflect the differences between northern European maritime, continental and Mediterranean climates, soils, altitude and topography, and the length of time a country has been in an industrial or post-industrial society. This latter reason for diversity relates to the social and cultural constraints placed on livestock systems. In the wider European Union with a common currency and economic policy, and a common environmental policy, some of the reasons for diversity that would have been important ten years ago are less important today. This diversity makes a review of improving resource use in ruminant systems difficult to undertake. Nevertheless, there are wide differences between dairy and meat systems, as well as within them, and this provides a starting point for the review of resource use options. Also, there are common technological advances that all ruminant systems can use and these are explored after a consideration of dairy and meat systems.

Dairy systems

Dairy systems based on cattle, sheep and goats, have shown a move towards increases in the herd size and the output per ruminant animal. This is illustrated in Table 1 for dairy cows in four countries in Europe over the last decade. The Table also shows the wide range in herd size and yields per cow. The objective of these systems is driven by solely commercial priorities. Increases in the genetic capability for yield have driven the development of systems which have led to greater use of nutrient –dense feeds, such as cereal- and protein-based concentrates, more housing and use of maize silage, greater frequency of milking and the use of robotic milking systems. The adoption of systems of this intensity have led to reductions in fertility, at least in dairy cows (Royal *et al.*, 2000), the increased incidence of lameness and mastitis ((Ingvartsen *et al*., 2003) and environmental problems of excessive surpluses of nitrogen and, in some cases, phosphorus. In Table 2 are shown some characteristics of intensive dairy cattle farms in the main European regions of milk production. It can be seen that, notwithstanding variations in the feeding management of the system, there are high surpluses of nitrogen from these systems. There are, therefore, major constraints to the further intensification of these systems in relation to nutrient use efficiency and the interaction between nutrition and disease which will be explored further below.

An alternative approach is to argue that greater economic returns can be achieved by improving the efficiency per litre of milk in part through reducing the costs of meeting environmental mitigation. Such systems will have a greater emphasis on the use of grazed grass in the diet of dairy animals and will be less intensive. Milk from these systems may need to obtain a premium, associated with the system of production, and need to have lower labour costs and other fixed costs, associated with simpler systems. It is likely that both system scenarios will develop in different regions of Europe. The implications for use of resources in both system scenarios are now considered.

Intensive systems

In the intensive scenario, one of the resources being optimized is the dairy animal because of its high genetic potential for milk yield. A major issue is that the evidence suggests that food intake potential has lagged behind milk output potential. Wilkins and Humphreys (2003) estimated that, whilst average milk yields had increased by about 100 % in the last fifty years, intake characteristics and digestibility of forages had increased by 1 % unit per decade. The implication of this is that the nutrient density of the diet has increased by increasing the proportion of concentrates in the diet to achieve higher nutrient intakes. This can lead to high substitution rates of forage by concentrate and the raising in importance of associative effects. Whilst their qualitative importance is well recognized, their quantitative significance in terms of the efficiency with which feeds are used has been elusive to establish. This applies as much to meat as to dairy systems.

New approaches to the prediction of intake and substitution rate are being developed both using empirical and mechanistic modeling approaches. McNamee *et al.* (2005) reported the use of an empirical approach which first of all predicted the intake of grass silage by dairy cows using a Near Infra-red Spectrometry (NIRS) calibration and then a simple model to predict grass silage intake when a known amount of concentrates was fed with 93% of the predictions of dry matter intake of silage within 10% of the actual values. These empirical approaches require a large amount of data to develop the calibrations and relationships used and are limited by the small range of forages and supplements that can be tested. A mechanistic approach to predicting substitution rates *inter alia* has been developed by Imamidoost and Cant (2005). They used non-steady state modelling of volatile fatty acid concentrations and inputs of the amount of concentrate, the timing and number of meals of concentrate, together with the composition of the forage and concentrate in terms of non-structural carbohydrate and degradable fibre – both measures could be obtained by NIRS, to predict the intake of forages. Figure 1 shows the predictions against field data on intakes of perennial ryegrass pasture by ewes in early lactation observed by Milne *et al.* (1981). The agreement between predicted and actual intakes was good. However, the authors claimed that the predictions could be improved by adding protein degradation and rumen microbial growth models and which would also provide additional predictions of nitrogen supply. Such a mechanistic approach has the potential to have a greater applicability than an empirical model and could be incorporated into decision-support tools to improve the use of feed resources and the prediction of milk production responses. There is a challenge to nutritionists to provide accurate predictions of responses in milk yield and composition and body composition change to inputs of forages and concentrates with the minimum number of easily measured variables.

In the operation of intensive dairy cow systems, a limitation is the costs of environmental mitigation. Surplus nitrogen at the farm scale provides a key indicator for the potential for loss and improvement of efficiency (Jarvis and Menzi, 2004). Whilst there is a strong positive relationship between nitrogen input and the rates of cycling, transfer and loss, efficiencies within different parts of the system control these rates and these can be improved. The most likely routes for improving efficiency are in manure management but it is essential that a lifecycle approach is taken and efficiencies in the conversion of feed N to product nitrogen can contribute not only to an increase in the efficiency of conversion to product but to a reduction in the rate of loss from the system.

Extensive systems

In grazing-based systems for dairy cows the priorities are likely to be to maximize daily herbage intake, through maintaining a high proportion of green leaf in the grazed sward, to extend the grazing season and to reduce nitrogen inputs through the use of pastures with a greater legume component (Peyraud *et al.*, 2004). The contribution of ruminant nutritionists is likely to be through improving the efficiency of the use of supplements, and indirectly through providing information to plant breeders on the appropriate balance between the energy and protein supply to the rumen. Extensive systems are likely to cause higher levels of methane production per unit of milk production than intensive systems because of a higher proportion of forage in the diet. There are a number of nutritional approaches that could lead to a reduction in methane production, for example higher dietary or forage lipid contents or the use of forages with a higher condensed tannin content (Woodward *et al.*, 2001).

The type of forage and the composition of pastures can influence the sensory quality of dairy products (Coulon *et al.*, 2004). The presence in milk of specific compounds, derived from the diet, such as carotenes or terpenes, or produced by the dairy animal under the effect of specific diets (plasmins or fatty acids) can affect the colour, texture, taste and smell of dairy products. This can be particularly so in mountain areas and in the Mediterranean area. It may also be possible to use the presence of such compounds as markers to protect the origin of the milk products. This area of research has the potential to provide "natural" products which consumer desires and is prepared to pay a premium for. The consumer is also interested in healthy foods and there is the potential to manipulate the fatty acids and fat-soluble micronutrients, such as carotenoids and vitamins A and E, in dairy products. They are higher on diets where the forage is at a young stage of development and where there is a higher plant diversity in the pasture although the easiest way to alter the composition of fatty acids in dairy products is to add oilseeds rich in polyunsaturated fatty acids (PUFA) in the diet. As Martin *et al.* (2004) concluded in a review "progress in the knowledge of the effects of these different diets on milk fatty acid composition could be used to develop new feeding strategies in order to increase the nutritional value of milk fat. Nevertheless, in other respects, milk or dairy products resulting from the addition of PUFA to the diet (from sources other than fresh herbage) could be more sensitive to oxidation. Further studies are needed to determine if antioxidants (e.g. Vitamin E) and/or other micronutrients could interact with PUFA metabolism in order to better control the potential effects of these feeding strategies on the organoleptic quality of dairy products".

Meat systems

Beef cattle and sheep systems for meat production are likely to remain or become more extensive, relying on grazed herbage, crop residues and inexpensive supplements in order to remain competitive with world market prices for beef and lamb. In such circumstances there is likely to be much reliance on simple systems since labour inputs per animal will be reduced either because herd and flock sizes will become larger or because there will be more part-time farmers.

Simple systems require less interventions by humans and hence nutritional research requires to focus on where the greatest return can be obtained from inputs of feed. For example, it has been demonstrated that the lifetime reproductive performance of ewes producing lambs for meat production can be increased by the level of feeding given to the fetus in pregnancy or in early post-natal life (Table 3, Gunn *et al*., 1995). Subsequent research demonstrated that, in the first trimester of pregnancy, under-nutrition influenced the pattern of development of the fetal ovary (Borwick *et al.*, 1997), offering another possibility whereby feed resources could be used strategically to influence lifetime performance. This example is given to demonstrate how a simple intervention of additional feed resources at one time in the life cycle can increase reproductive rate over a lifetime by 15%. Conversely, it demonstrates also that a short-term reduction in feed inputs can lead to long-term effects that may not have been considered. It is those types of intervention that future simple systems will be seeking to optimise. It may be that research on the allocation of feed resources over a lifetime may have a greater cost benefit than the same resources used to test whether one supplement is better than another.

The same type of argument applies to the use of anthelmintics, particularly in young sheep and goats, to control nematode species. The continued use of anthelmintics leading to the development of resistance to them is unsustainable and not cost-effective. Furthermore, increased public awareness of drug residues and the impact on the environment of the ecotoxicological effects of their excretion on beneficial soil microfauna will lead to limitations on their use. New approaches combining increased genetic resistance to infection with increased metabolizable protein supply in the peri-parturient period to influence a cell-mediated immune response and with new grazing management strategies, for example incorporating tanniferous forages, suggest a way forward (Coop and Sykes, 2002). This requires a whole system approach involving geneticists, parasitologists, immunologists, agronomists and nutritionists.

It is also likely that there will be considerable economic pressure to obtain a premium from the production of a specialist (for example 'diet and health' foods) or regional products produced in a particular manner. According to human nutritionists, the proportion of saturated fat in the human diet should be less than 10 % and the ratio of unsaturated to saturated fat should be less than 0.45 with the n-3 polyunsaturated fatty acids (PUFAs) being increased relative to n-6 PUFAs. Since meat is a major source of saturated fats, there is considerable interest and pressure from consumers to alter the composition of fat in ruminant meats. While the use of fish oils to achieve this is unlikely to meet favour with consumers or regulators, plant oils, such as linseed oil, may be possible to use. Also fresh forages offer an opportunity to increase the content of conjugated linoleic acid. There is also the issue of off-flavours and colour changes in the fat to be considered. Because of the role of biohyrogenation in the rumen and its variable nature, there is some way to go to predict the composition of fat from the composition of the diet. This is a challenge for nutritionists and meat scientists.

The income of farmers could also be augmented in beef cattle or sheep systems by contributing towards the delivery of environmental benefits often in relation to biodiversity and landscape objectives. The multi-functionality of grasslands poses problems in that a management system to optimize one function may not optimize another function. A simple example is the management of grasslands for nesting birds which restricts the making of conserved forage to a later date which reduces the feeding quality of the conserved forage and may alter the grazing management of adjacent area. There are also methodological difficulties in predicting with any precision the nutritive value of complex semi-natural grasslands or rangelands (Bruinenberg *et al*., 2002). Moreover to increase the nutritive value of forage harvested at the optimum to meet nature conservation objectives may require chemical treatment of the forages. Multispecies systems may also be required to meet nature conservation needs and this also increases the costs of providing such a system. As part of wider systems studies, involving economists and systems modelers, ruminant nutritionists have a role to play in determining the feasibility of solutions and determining opportunity costs.

Conclusion

Specific issues have been identified in the paper for improving resource use in milk and meat systems in Europe, but there are also a number of general issues which should be addressed. Dairy systems require increased precision in the nutritive value of feeds and their combinations and the efficiency with which nutrients are utilized. Meat systems from ruminants often seek to use feed by-products more effectively and utilize alternative feeds. In terms of management strategies, diary systems are developing management strategies which minimize the impact of external constraints, such as environmental legislation, whilst meat systems may seek to alter management to obtain the benefits that can arise from environmental management. However, there are common technological advances that all ruminant systems seek to use. Examples of these are in the modelling of the responses of ruminants to predominantly forage-based systems, the increase in the understanding of the interaction between nutrition, management and disease, and the role of dietary manipulation in providing animal products to meet consumer demands. These are areas where ruminant nutritionists can make important advances whilst at the same time contributing in multi-disciplinary groups to the development of milk and meat production systems to meet the needs of the next decade.

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Table 1 Changes in annual milk yield and herd size in four selected countries of Europe between 1991 and 2001 (Dairy Facts and Figures, 2002; from Oldham and Dewhurst, 2004)

Country	**1991**		**2001**	
	Milk yield (kg/year)	**Herd size**	**Milk yield (kg/year)**	**Herd size**
UK	5268	69	6505	73
Denmark	6169	39	7231	57
France	5165	27	5887	33
Spain	4211	9	5503	18

Table 2 Characteristics of intensive dairy farms in some European regions (from Pflimin *et al.,* 2004)

	Netherlands	**UK**	**Italy**	**Ireland**
Milk/ha (tons)	13.4	7.4	11.0	7.2
% grazed grass	30	45	0	75
Surplus N (kg/ha)	400	280	240	200

Table 3 The effect of fetal (F) and neonatal (N) nutrition on the weaning live weight and subsequent reproductive performance (Proportion producing multiple births) of Scottish Blackface ewes (Gunn *et al.*,1995).

Feeding level	**Weaning weight (kg)**	**Lamb crop 1**	**Lamb crop 2**	**Lamb crop 3**
Low (F+N)	30.7	0.30	0.47	0.55
High (F)	31.9	0.42	0.55	0.68
High (N)	31.4	0.44	0.60	0.67