

Protein nutrition for ruminants in European countries, in the light of animal feeding regulations linked to bovine spongiform encephalopathy

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Summary

The outbreak of bovine spongiform encephalopathy (BSE) and the discovery of the central role played by meat-and-bone meal (MBM) as the vehicle of infection resulted, from the late 1980s onwards, in the implementation of new regulations on the incorporation of animal proteins, and then of most fats of animal origin, into diets fed to ruminants and other farmed animals. The BSE-related feed ban, which has gradually been reinforced over time, has led to the investigation of cost-effective routes for adequately replacing MBM and tallow by new sources of dietary proteins, minerals and lipids in the formulation of manufactured concentrates. As far as the technical fulfilment of the nutritive requirements of growing and lactating ruminants is concerned, efficient alternative solutions, based principally on recourse to food materials from vegetables already exist or hopefully will soon be available in most of the situations prevailing in Europe. However, related aspects, such as animal feed-processing, availability and traceability of certain food materials, quality of animal products, environmental constraints or disposal of animal waste from the meat industry give cause for concern. The expected consequences of the BSE-related feeding regulations on the organisational and economic framework of animal and crop production sectors throughout Europe and at world level must also be evaluated.

Keywords

Animal feed ban – Bovine spongiform encephalopathy – Dietary animal fats – Feeding management – Meat-and-bone meal – Nutrition – Plant food materials – Ruminant.

Introduction

Natural scrapie, a degenerative disease affecting the central nervous system of domestic sheep, and less commonly of domestic goats, has been known for over two hundred years in Great Britain and other countries in Europe. Research on this progressive and invariably fatal neurological disorder began in the 19th Century, and theories on the cause and the mode of transmission of the disease have been debated for many years (14, 15).

According to Prusiner *et al.* (38, 39), the scrapie agent is an infectious protein, i.e. an abnormal form of a host-encoded protein, prion protein (PrP), which accumulates in the central nervous system of affected animals (PrP for prion-proteinaceous infectious particle-protein). Investigations on

natural and experimentally induced scrapie in sheep have shown that genetic susceptibility to the disease is modulated by at least three different codons (136, 154, 171) of the sheep PrP gene. Studies reported so far on the PrP genotypes relevant to the scrapie susceptibility status reveal the resistance of homozygous ARR/ARR (ARR: alanine, arginine, arginine) animals and the high liability to disease of VRQ/VRQ (VRQ: valine, arginine, glutamine) and VRQ/ARQ (ARQ: alanine, arginine, glutamine) animals in scrapie-affected flocks (47).

However, a new disease, referred to as bovine spongiform encephalopathy (BSE), emerged in the mid-1980s in the United Kingdom (UK), and the first case of BSE was confirmed in November 1986 on the basis of histopathological examination of affected brains (57). Rapidly, BSE was recognised as being a new member of the scrapie-like family of neurodegenerative diseases. This finding provided new impetus

for research on the class of sub-acute, transmissible spongiform encephalopathies (TSE) comprising BSE, scrapie and some rare human diseases such as Creutzfeldt-Jakob disease (CJD) and the BSE-ascribed variant of CJD (vCJD).

Epidemiological inquiries conducted on BSE led British researchers to conclude that the main, and perhaps only, vehicle of infection was meat-and-bone meal (MBM) which had been incorporated into concentrate feeds given to cattle during the previous years (58). Meat-and-bone meal was essentially used as an ingredient of such concentrates – with rates of incorporation of a few percentage points – because of the high content in crude protein and major mineral elements of the material.

The proven link between BSE and animal feeding practice soon resulted in the introduction of new regulations establishing rules for the incorporation of protein of animal origin into animal diets. As a consequence, there has been a pressing need for reconsidering the way in which the protein requirements of farmed animals (cattle and others) could be fulfilled. More recently, the BSE-related feed ban was extended to most fats of animal origin, which raised a series of new questions relating to energy and lipid nutrition.

The scope of this paper will be restricted to the feeding management of ruminant animals in the new context in Europe where the use of animal by-products as food materials is prohibited.

Historical background of the food-borne hypothesis for bovine spongiform encephalopathy

From early investigations performed after the advent of BSE in the UK, several lines of evidence pointed to the fact that BSE was not a disease of genetic origin and host genetic variation (e.g. polymorphisms in the PrP gene, as found for scrapie) was not of great importance. In addition, the occurrence of BSE could not be traced back to the importation of cattle, the use of semen for artificial insemination, the movement of animals between herds or the simultaneous presence of cattle and sheep on the same farm. In view of the typical distribution of clinical cases of BSE over time, it could be anticipated that the disease was due to an extended common source epidemic. Every BSE case appeared to be a primary case and there was no firm evidence for the direct transmission of infection from cattle to cattle.

The only common factor to be identified among the early cases of BSE reported in the UK was the consumption of infected

compound feeds by the animals which developed the disease (58). At that time, two animal-derived by-products of the rendering industry were incorporated into commercial concentrates fed to ruminants, namely MBM and tallow, but the former was a much more likely vector of contamination than the latter.

A comparison of BSE incidence in cattle farms with only home-bred cases showed that the proportion of affected dairy herds was about fifty times greater than that of beef herds. A common practice in dairy herds in the UK consisted of feeding concentrates containing MBM, not only to lactating cows, but also to young calves, usually reared away from their mothers. In contrast, such concentrates were scarcely used within the first six months of life for beef-suckler calves, reared on their mothers and weaned at six to eight months of age. Moreover, a case-control study carried out in the early 1990s by Wilesmith *et al.* (59) showed that the presence of MBM in manufactured concentrates intended for young calves was a statistically significant risk factor for the occurrence of BSE.

These salient features as well as some other facts reviewed by Kimberlin (30) favoured the food-borne hypothesis for BSE and, more precisely, the role of contaminated MBM in the outbreak of the disease. This outbreak was perhaps initiated by scrapie infection of cattle, even though other sources of infection are possible and the real origin of the disease will probably never be known with certainty (19). However, regardless of the initial origin of BSE, the subsequent course of the epidemic was probably driven, and actually boosted, by the recycling of infected cattle material within the bovine population.

In the Horn committee report published in July 2001, several features of the BSE story have been re-evaluated and, in particular, special emphasis has been placed on the major importance of young calf feeding practices in the epidemic which occurred in the UK (26). This report argued that the feeding of cattle very early in their lifespan with contaminated MBM played a greater role than was formerly thought: there appears to be an age-related susceptibility to BSE and young calves could exhibit a higher liability to become infected by the oral route than older individuals. The principal argument advanced by the Horn committee was that the practice of feeding MBM to calves in their first few weeks of life has seemingly been restricted, and is perhaps unique, to the UK, i.e. the country in which BSE emerged and showed by far the highest incidence. This opinion is not shared by all the scientists working on BSE and new pathogenesis studies should be conducted to test the hypothesis of age-related susceptibility to this disease. However, interestingly, the BSE-ascribed new variant of human CJD appears to affect predominantly young people.

For completeness, it should be recalled here that a number of hypotheses exist for the sources of BSE transmission other than

the consumption of MBM contaminated with the causal agent of the disease. As inventoried and thoroughly discussed in November 2001 by the TSE/BSE ad hoc Group of the European Community (19), alternative hypotheses for BSE transmission include: consumption of infected ruminant- or mammalian-derived food materials other than MBM (e.g. gelatine prepared from skin and bone or fat), maternal transmission – this route of transmission is strongly suspected to occur, via the placenta, for natural scrapie in sheep and epidemiological studies suggest that some form of maternal transmission would explain around 10% of BSE cases –, and a large number of possible ‘third ways’ such as environmental contamination (e.g. parasitic nematodes, contaminated water or soil fertilisers) or iatrogenic transmission (e.g. vaccines or other medicinal products derived from TSE-susceptible species). In addition, genetic factors or ‘collateral’ factors (e.g. mineral imbalance or exposure to certain chemical compounds) might also increase susceptibility to the disease.

Novel bovine spongiform encephalopathy-related regulations regarding animal feeding

From 1988 onwards, the BSE outbreak in the UK and other countries in Europe led national governments and the European Commission to introduce new regulations on the use of animal by-products (essentially MBM) for feeding cattle,

small ruminants and other farmed animals. A number of key steps in this respect are reported in a summarised form in Table I.

In the UK, the original 1988 ban on feeding ruminant protein to ruminants was followed by a ban on the feeding of mammalian protein to any farmed livestock in 1996. This reinforcement of the feed ban was introduced in order to prevent the risk of cross-contamination of ruminant feeds by feeds intended for other livestock species such as pigs and poultry. Such cross-contamination had indeed been strongly suspected in certain cases of BSE occurring in animals born after the original feed ban.

A similar approach, consisting of the enforcement of gradually tightened rules, has been followed by the Government in France (feed ban formerly limited to cattle, then extended to other ruminant species and now to all farmed animals) and by the authorities of the European Community (20).

Animal by-products for ruminant feeding

Incorporating animal by-products into compound feeds for farm animals has been a widespread practice for several decades throughout the world. Furthermore, contrary to common belief, MBM began to be introduced into non-forage feeds for cattle more than a century ago.

Table I
Principal key dates for regulations pertaining to the feeding of animal-derived products to ruminants and other farmed animals

Year	Country ^(a)	Event
1988	United Kingdom	Ban on the feeding of ruminant protein (except that from milk) to cattle and other ruminants
1990	United Kingdom	Ban on the feeding of meat-and-bone meal (MBM) derived from specified bovine offals to all animal species
1990	France	Ban on the feeding of MBM to cattle
1994	European Community (1994/381/EC)	Ban on the feeding of proteins derived from mammalian tissues to all ruminant species
1994/1996	European Community (1994/382/EC and 1996/449/EC)	Conditions required for the pressure-cooking processing of mammalian/ruminant waste for MBM with regard to the inactivation of the bovine spongiform encephalopathy (BSE)/transmissible spongiform encephalopathy (TSE) agents ^(b)
1996	United Kingdom	Ban on the feeding of MBM of mammalian origin to all farmed animals
1997	European Community (1997/735/EC)	Restrictions on MBM trade
1999	European Community (1999/534/EC)	Conditions for the production of MBM and tallow
2000	France	Suspension of the use of proteins and fats of animal origin for feeding all farmed animals ^(c)
2001	European Community (2001/9/EC)	Conditions for feeding certain animal proteins
2001	European Community (R999/2001)	‘TSE regulation’ containing specific prohibitions for Member States or regions with high incidence of BSE (category 5): no feeding of mammalian processed or unprocessed protein to any farmed animal, no feeding of ruminant fat to any ruminant
2002	European Community (2002/248/EC)	Amendments with regard to the feeding of animal proteins to farmed animals which are kept, fattened or bred for the production of food

a) For more details on European Community legislation and French regulations, see the references of the European Community (20) and Perez *et al.* (37), respectively

b) Heating at a temperature of 133°C and a pressure of 3 bar for a minimum of 20 minutes

c) Ruminant trimming fat taken prior to carcass splitting and submitted to a compulsory heat-treatment as well as pig fat were again authorised in 2001 for feeding all farmed animals

These products of the rendering industry consist of waste material essentially derived from abattoirs and boning-out plants. In brief, the rendering process consists of cooking raw material at high temperatures to remove water, followed by mechanical separation of fats (tallow) and grinding of the solid protein-rich residue to obtain MBM. The latter was considered for a long time as providing, at a comparatively low cost, a valuable and easily available source of proteins and essential amino acids for use in animal feeds.

Table II provides an overview of the compositional and nutritive characteristics of a number of food materials used for ruminants, enabling animal by-products (MBM and tallow) to be placed among other feedstuffs in terms of potential interest for ruminant rations. In the table, food materials are ranked according to the crude protein content of dry matter and the data reported relate to the following:

– net energy value, either for milk or meat production (52, 55)

– protein value, defined as the supply of proteins and amino acids truly digestible in the small intestine, according to the proteins digestible in the intestine (PDI) and amino acids truly digestible in the small intestine (AADI) feed evaluation systems (43, 52, 53)

– content in two major mineral elements, namely: phosphorus and calcium.

Meat-and-bone meals

Meat-and-bone meals show great variability in chemical composition and nutritional value, mainly depending on the proportion of bone in the raw material and the extent to which the material is defatted. The data reported in Table II refer to the average characteristics of defatted and non-defatted MBM. The potential nutritive interest of MBM resides in the high crude and digestible protein and macro-mineral element (phosphorus, with high bio-availability, and calcium) content of the material.

Table II
Compositional and nutritional characteristics of some food materials for ruminant diets, as ranked according to total nitrogen (N) content per kg dry matter (DM)

Food material	Total N ^(a)	DM (%)	Net energy value		PDIE ^{(a)(c)}	Protein value		Minerals	
			Milk fodder unit ^(b)	Meat fodder unit ^(b)		Di-Lys ^(d)	Di-Met ^(d)	Phosphorus ^(e)	Calcium ^(e)
Defatted meat-and-bone meal	551	93	0.53	0.52	265	ND	ND	52	110
Meat-and-bone meal	538	95	0.70	0.67	257	ND	ND	48	100
Soybean meal	516	88	1.21	1.20	261	6.9	1.5	7.1	3.9
Formaldehyde-treated (FT) soybean meal	516	88	1.21	1.20	426	6.8	1.4	7.1	3.9
Rapeseed meal	380	89	0.96	0.90	156	6.8	2.0	12.9	9.4
FT rapeseed meal	380	89	0.96	0.90	277	6.5	2.0	12.9	9.4
Corn gluten feed	219	88	1.06	1.03	116	6.3	2.0	10.1	1.8
Dehydrated lucerne	174	91	0.68	0.60	100	6.7	1.8	2.6	21.7
Green forage ^(e)	172	17	0.97	0.92	95	6.9	1.9	4.0	7.0
Wheat bran	170	87	0.94	0.88	92	6.7	1.9	11.4	1.6
Wheat grain	121	87	1.18	1.18	103	6.7	1.9	3.7	0.8
Grass silage ^(e)	117	21	0.80	0.72	69	7.0	1.9	3.0	6.5
Barley grain	116	87	1.10	1.07	100	6.8	1.9	3.9	0.8
Hay ^(e)	104	85	0.72	0.63	77	7.1	1.9	3.0	6.0
Corn grain	94	86	1.23	1.23	97	5.7	1.9	3.0	0.5
Dehydrated sugar beet pulp	91	89	1.00	0.98	109	7.9	2.0	1.0	14.8
Maize silage	84	30	0.70	0.59	66	6.9	2.0	2.5	3.5
Animal fats	0	99	2.76	2.83	0	0	0	0	0

ND: no data

a) In g per kg dry matter (DM)

b) 'Feed units' per kg DM, either for milk (milk fodder unit) or meat (meat fodder unit) production. For details on the feed unit system in France, see Vermorel (55, 56)

c) PDIE: protein truly digested in the small intestine, i.e. the sum of digestible dietary proteins undegraded in the rumen and digestible microbial proteins corresponding to the dietary energy fermented in the rumen. For details on the proteins digestible in the intestine (PDI) system in France, see Vérité *et al.* (52) and Vérité and Peyraud (53)

d) Digestible lysine and methionine in g per 100 g PDIE. For details on the system of amino acids truly digestible in the small intestine (AADI) in France, which is integrated into the PDI system, see Rulquin *et al.* (43)

e) From permanent meadows, used at the 'ear' stage

Source: Andrieu *et al.* (1), Rulquin *et al.* (43), Sauviant *et al.* (45)

Regarding the former aspect, the protein value of feeds for ruminants depends largely on the extent to which feed proteins escape microbial degradation in the rumen and is therefore based on an estimation of the quantity of dietary and microbial proteins absorbed in the small intestine. Table II shows that soybean or rapeseed meals are grossly comparable to MBM – and even better following formaldehyde treatment – in terms of supply to ruminants of proteins truly digestible in the small intestine. The dietary nitrogen fraction escaping ruminal degradation is approximately 0.50 for MBM, which is higher than that for grass forages and cereals (except corn), but lower than that for formaldehyde-treated (FT) soybean, rapeseed or sunflower meal (53).

According to Sauvant and Michalet-Doreau (44), the main technical limits to the use of MBM in ruminant diets relate to the low appetite and to the problems often encountered in storage and conservation of the material.

Animal fats

The nutritive interest of animal fats (beef tallow or lard) is primarily associated with their high net energy value, by far superior to that of any other food material quoted in Table II (2.8 versus 0.6 to 1.2 'feed units' per kg dry matter). Adding fats to the diets given to growing and lactating cattle therefore enables the energetic density of the diets to be increased and improves the overall efficiency of energy utilisation for animal performance (16, 28, 35).

Compared with vegetal oils or oil-producing seeds such as soybean, rapeseed and sunflower, animal fats show greater percentages of saturated fatty acids and lower percentages of polyunsaturated fatty acids (PUFA) (34, 45). The fact that animal fats are richer in saturated fatty acids is favourable, for example, in the case of veal calf production (50). In addition, the unfavourable digestive interactions induced by dietary lipids in the rumen seem to be less important with animal than with more unsaturated vegetal fats (44).

Tallow was principally used for incorporation into compound diets ('milk substitutes') fed to pre-ruminant young animals, e.g. veal calves. However, the incorporation of dietary lipids (animal or vegetal fats) was also a fairly usual practice for dairy cows, especially in the first six weeks of lactation, and for growing beef cattle, especially in the fattening-finishing period (8, 9, 12, 36).

Protein sources for ruminant feeding

Prohibition of the feeding of mammalian protein to ruminants (and, gradually, to other farm animals) in countries in Europe

has raised at least two important questions for the agro-industry sector, as follows:

- how to supply dietary proteins and minerals to ruminants in an adequate and cost-effective manner
- how to store and safely dispose of the animal waste material which inevitably results from the activities of abattoirs and other sectors of the meat industry.

The latter question will not be treated here in detail, although the problem is real and complex since some 15 million tonnes of raw animal waste are produced each year in the European Union (EU). A variety of processing or disposal routes such as incineration, burial and/or landfill, biogas production and composting (for use as fertilisers) are currently in use, and other possible biological routes are under study. Low risk animal by-products are still used in the pharmaceutical and cosmetic industry and for making compound feeds intended for animals whose flesh does not enter the food chains, such as pets and fur animals. The pet-food industry appears to be a significant outlet for low risk animal by-products in some countries. A survey of the situation prevailing across the EU for the processing, disposal and uses of animal by-products has recently been published by the European Community (18).

For more than 25 years, i.e. much prior to the ban on MBM, ruminant nutritionists have focused research efforts on increasing the flow of amino acids delivered to the intestine (7, 27, 60), with special emphasis placed on the feeding management of lactating cows (11, 51).

A number of significant advances have been obtained in this respect and have greatly facilitated the implementation of efficient alternative solutions for ruminant diet formulation to manage the ban on dietary protein of animal origin.

Three main approaches have been investigated, as follows:

- a) inclusion of protein sources in the diet which are not readily degraded by microbial enzymes in the rumen and which pass to the small intestine, thereby increasing the amount of dietary amino acids available for absorption
- b) optimisation of ruminal fermentation in order to benefit from the microbial protein synthesis occurring within the rumen, thereby increasing the amount of microbial amino acids available for absorption
- c) addition to the diet of encapsulated forms of specific amino acids (or amino acid analogues) which are more or less protected against ruminal degradation.

As mentioned above, ruminal degradation of dietary nitrogen varies widely among feedstuffs. Special processing of certain food materials can modify this rate of degradation. For example, FT of soybean, rapeseed or sunflower meals significantly decreases the 'theoretical degradability' of nitrogen

in the rumen: 0.26 to 0.30 versus 0.63 to 0.77 (41). Microbial protein synthesis appears to be unaffected by properly applied FT, so that the protein value of FT meals as expressed in terms of PDIE (protein truly digested in the small intestine, i.e. the sum of digestible dietary proteins undegraded in the rumen and digestible microbial proteins corresponding to the dietary energy fermented in the rumen) is markedly higher than that of corresponding non-treated meals (Table II).

With a supply of 370 g PDIE per kg raw matter, FT soybean meal is an excellent protein supplement for ruminants, although the material contains a comparatively small amount of digestible methionine per unit of PDIE. However, FT soybean meal compared with non-treated meal significantly lowers the protein content of milk (33). In spite of 35% to 40% lower PDIE levels than FT soybean meal, FT rapeseed or sunflower meals are also of great interest as protein supplements due to their fairly high content in digestible methionine per unit of PDIE.

The development of methods to protect amino acids from microbial degradation in the rumen has enabled diet supplementation with specific amino acids which become available for absorption at intestinal level. Different procedures of protection exist, but these basically consist in the coating amino acids with various substances (32, 41, 46).

To date, the production of ruminally protected forms of pure amino acids has been investigated most thoroughly for methionine and, to a lesser extent, for lysine. The particular attention focused on methionine is due to the fact that this substance appears to be the first limiting amino acid for the synthesis of milk and milk protein by dairy cows, especially when grass silage is the main forage consumed (42). Moreover, similarly to histidine, increasing the concentration of methionine in diets through the use of classical protein-rich food materials issued from plants to reach the recommended allowance for high-producing dairy cows is very difficult (41).

In the early part of lactation, a proportion of high-yield dairy cows exhibit hepatic steatosis, with maximum occurrence at four weeks after calving (24, 40). The combined use of protected methionine and lysine decreases lipid deposition in the liver during the first eight weeks of lactation (3) and thus greatly limits the risk of this disorder which is known to have harmful effects upon the health, reproductive performance and milk yield of dairy cows (23).

With the emergence of environmental concern, the recent trend in protein nutrition of ruminants and evaluation of feeding systems has been to take into account, not only the improvement of animal performance and feed efficiency, but also the management of excreta-derived nitrogen flow delivered to the environment (49). This novel preoccupation is linked to the recognised role of excess nitrogen in certain environmental attacks. Even though ruminants compared with 'off-soil'

animals are closely associated with the agricultural lands upon which they are fed, they contribute significantly to the vast problem of exceeding amounts of nitrogen waste in intensive animal production areas.

As outlined by Vérité and Delaby (54), nitrogen excretion by ruminants is principally related to nitrogen intake, which can be controlled through the forage species in use and protein supplementation of diets. The latter aspect is the easiest to control on technical grounds. However, in practice, the crude protein content of diets is sometimes increased beyond recommended allowances with the expectation of some positive effects on performance while not accounting for the extra cost of the diet and the extra nitrogen waste. Today, the challenge in ruminant protein nutrition is therefore to develop a balanced strategy between the favourable effects of increased dietary protein supply on performance levels and feed efficiency of animals and the unfavourable effects on the amount of nitrogen restitution to the environment.

In recent years, several of the plant species used as ingredients of animal feeds have been subject to genetic modifications (GM) operated by recombinant deoxyribonucleic acid (DNA) technology. Among the crops concerned by GM-induced tolerance to various herbicides or resistance to insects or viruses (21), soybean and rapeseed are currently used to a large extent as protein sources in concentrates fed to ruminants in countries in Europe. Table III shows the situation in 2001 in France regarding the ingredients incorporated into manufactured concentrates fed to dairy cows and beef cattle. The possible use of novel transgenic plant materials has raised the controversial question of their safety for farmed animals, and further, for the human food chain. Most of the important issues addressed by the recourse to genetically modified varieties of plants as food materials for farmed animals have been comprehensively reviewed and discussed by Aumaitre *et al.* (2).

Table III
Average composition (%) of manufactured concentrates used for cattle feeding in France in 2001

Food material	Dairy cows	Beef cattle
Cereal grains (wheat, barley, corn)	14	23
Cereal by-products from milling and starch industry (wheat bran, corn gluten feed)	21	17
Soybean meal	22	17
Rapeseed and sunflower meals	15	20
Dehydrated sugar beet pulp	12	10
Dehydrated alfalfa	6	3
Molasses	3	3
Peas	2	2
Oil-producing seeds	1	1
Vegetal oils	1	1
Minerals	3	2

Source: Syndicat National des Industriels de la Nutrition Animale (SNIA) (48)

Sources of mineral elements for ruminant feeding

Similarly to nitrogen, a global approach based upon considering both performance levels and environmental constraints must be followed regarding phosphorus supply to ruminants since more than half of the phosphorus waste of animal origin derives from ruminants (49). This approach requires, among other things, the accurate determination of ruminal phosphorus availability of different feedstuffs. For example, formaldehyde treatment of certain food materials decreases ruminal phosphorus availability and could depreciate the nutritive value of the element from FT meals (6).

The replacement of MBM, rich in phosphorus of excellent bio-availability, by plant materials containing less phosphorus of lower bio-availability requires that greater amounts of phosphorus of mineral origin be added to ruminant diets. This increased use of mineral phosphates results in larger recourse to non-renewable resources at the world level. Moreover, it could also be accompanied by a greater waste of traces of metal contained in mineral phosphates, whereas MBM is free of these trace elements (37).

Lipid sources for ruminant feeding

Although there had been increasing interest in the last two decades in the addition of fats to the diets of growing and lactating cattle, the most critical problem raised by the recently promulgated ban on most animal fats for ruminant feeding pertains to the formulation of milk substitutes fed to young pre-ruminant animals. These milk substitutes are indeed very rich in fat since they usually contain approximately 200 g fat per kg dry matter.

Beef tallow and lard were the most commonly used sources of fat for pre-ruminant calves due to their adequate fatty acid composition for calf performance, their availability and comparatively low cost. Given the new BSE-related regulations, the replacement of these animal fats by vegetal oils from palm, soybean, rapeseed or coconut palm has become necessary in countries of the EU.

Studies have shown that vegetal oils very rich in PUFA such as soybean oil (> 60% PUFA), given to calves as the sole source of fatty acids induce hypercholesterolaemia, hepatic steatosis and detrimental effects on health, appetite and growth rate of the animals (29, 31). Similar deviations of hepatic lipid metabolism and impairments of calf health and performance have been observed when milk replacers solely based on coconut oil, a food material very rich in saturated medium-chain fatty acids (MCFA), are given to pre-ruminant calves over a long period

(4). In the latter case, lipid infiltration in the liver would be caused by a decrease of apolipoprotein B (ApoB) synthesis, resulting in the reduction of hepatic secretion of very-low-density lipoprotein particles (25).

In light of these results showing the inadequacy of diets based on a sole source of vegetal fat, research efforts are focusing on developing new types of milk substitutes containing several plant fats in an attempt to reproduce a balanced fatty acid composition close to that of beef tallow, i.e. with low proportions of both PUFA and MCFA. Milk substitutes consisting of an appropriate mixture of partially hydrogenated palm, soybean and coconut oils appear to provide satisfactory results in terms of health, growth performance and carcass quality of veal calves (D. Bauchart, personal communication).

The manner in which lipid nutrition of growing and lactating animals is viewed has evolved considerably in the last ten years and integrates aspects other than the sole consideration of dietary lipid supplementation as a source of energy. Increasing attention has been paid to improving the dietetic value, for human consumers, of food products of animal origin. Several recent studies have shown that certain feeding strategies in ruminant animals can exert a significantly favourable influence on the health value of milk and meat. In particular, the lipid supplementation of rations by protected or unprotected animal or vegetal fats is an effective route for modulating the fatty acid composition of animal products (13).

The main points of interest in this respect deal with, on one hand, the saturated and trans-C18:1 fatty acids, which have a putative harmful influence on human health, and, on the other hand, the n-3 PUFAs (C18:3, C20:5, C22:6) and the conjugated linoleic acid (CLA) isomers, which have potentially positive effects on human health. Certain vegetal fats (e.g. those from linseed and sunflower seed) as well as fish oils appear to be of special interest for generating a better dietetic value of milk (10) and meat (5, 17, 22). However, the possible side-effects of feed management on the health and welfare of animals, as well as on the sensory and technological qualities of products, must be accounted for when defining the objectives to be pursued regarding lipid composition of ruminant diets.

Conclusion

Undoubtedly, the ban on feeding of MBMs and most animal fats to farmed animals has been a cause for concern to the animal production sector in Europe in the last decade. The consequences of this change are fairly complex and cover a variety of aspects, namely: feed management of animals (formulation of diets with regard to proteins, lipids and macro-minerals, cost of diets, supply and traceability of certain food materials imported to Europe from other continents), feed-processing (e.g. technological implications of the withdrawal of animal fats), sensorial qualities and processing ability of animal

products (e.g. effects of the replacement of animal fats by vegetal oils or seeds), environmental impact of animal production (excretion of nitrogen, phosphorus, traces of metal), processing or disposal of animal waste from the meat industry.

The overall review by Perez *et al.* (37) shows that the repercussions of the BSE-related animal feeding regulations have probably been more critical and difficult to solve for monogastric species (poultry, pigs) than for cattle and small ruminants. However, at this stage, as far as nutritional grounds are concerned, efficient alternative solutions already exist, or will be available soon, for the substitution of MBMs and fats of animal origin in most of the situations prevailing in countries in Europe. Beyond this technical point of view, expected

consequences on the organisational and economic framework of the animal and crop production sectors at both European and world levels should be accurately evaluated in a mid- or long-term perspective.

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L'apport protéique aux ruminants dans les pays européens après prise en compte de la réglementation sur l'alimentation des animaux liée à l'encéphalopathie spongiforme bovine

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Résumé

L'épizootie d'encéphalopathie spongiforme bovine (ESB) et la découverte du rôle primordial joué par les farines de viande et d'os (FVO) dans la transmission de l'infection ont entraîné la promulgation, à partir de la fin des années 1980, de nouvelles réglementations. Ces dernières ont régi l'incorporation des protéines animales, et ultérieurement de la plupart des graisses d'origine animale, dans les rations destinées aux ruminants et aux autres animaux d'élevage. Le durcissement progressif de cette réglementation liée à l'ESB a rendu nécessaire la recherche de méthodes rentables permettant de remplacer la FVO et le suif par de nouvelles sources de protéines, de minéraux et de lipides alimentaires dans la formulation des concentrés. Sur le plan technique, des solutions de remplacement efficaces existent déjà (ou devraient bientôt voir le jour) et permettent de satisfaire les besoins nutritionnels des ruminants en période de croissance et de lactation. Ces solutions, qui reposent essentiellement sur l'utilisation d'aliments dérivés de produits végétaux, devraient répondre aux conditions généralement rencontrées en Europe. Toutefois, certains aspects connexes ne laissent pas d'inquiéter comme, par exemple, la technologie de fabrication des aliments concentrés pour animaux, la disponibilité et la traçabilité de certaines matières premières, la qualité des produits d'origine animale, les contraintes environnementales ou l'élimination des déchets d'origine animale issus de la filière de la viande. Par ailleurs, il conviendra d'évaluer les répercussions des réglementations relatives à l'alimentation des animaux, introduites après l'épizootie d'ESB, sur l'organisation et l'économie des filières de production animale et végétale au niveau européen et international.

Mots-clés

Aliment d'origine végétale – Encéphalopathie spongiforme bovine – Farine de viande et d'os – Gestion de l'alimentation des animaux – Graisse alimentaire animale – Interdiction relative à l'alimentation des animaux – Nutrition – Ruminant.

Aporte de proteínas en la alimentación de los rumiantes en los países europeos, habida cuenta de la reglamentación sobre alimentación animal vinculada a la encefalopatía espongiforme bovina

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Resumen

La epizootia de encefalopatía espongiforme bovina (EEB) y el descubrimiento de que la infección se había transmitido a través de las harinas de carne y huesos hicieron que a partir de finales de los años ochenta se promulgara una reglamentación novedosa sobre la introducción de proteínas animales (y posteriormente de buena parte de las grasas de origen animal) en las raciones proporcionadas a los rumiantes y otros animales de granja. La prohibición ligada a la EEB, progresivamente endurecida con el tiempo, obligó a buscar formas rentables de sustituir las harinas de carne y huesos y el sebo por nuevas fuentes de nutrientes (proteínas, minerales y lípidos) en la formulación de concentrados. Por lo que a Europa respecta, y en casi todas las circunstancias que se dan en el continente, existen o cabe esperar que pronto existan soluciones técnicas alternativas y rentables para satisfacer los requisitos de nutrientes de los rumiantes en crecimiento o lactación, basadas sobre todo en el uso de derivados vegetales. Sin embargo, hay una serie de aspectos conexos como el procesamiento de los piensos, la disponibilidad y rastreabilidad de determinados productos alimenticios, la calidad de los productos de origen animal, las restricciones ambientales o la eliminación de los desperdicios animales de la industria cárnica que siguen planteando problemas. Es preciso asimismo evaluar las previsibles consecuencias que las normas de alimentación animal vinculadas a la EEB tendrán sobre la estructura organizativa y económica de los sectores agropecuarios, a escala tanto europea como mundial.

Palabras clave

Encefalopatía espongiforme bovina – Gestión de la alimentación animal – Grasa animal alimentaria – Harina de carne y huesos – Nutrición – Producto alimentario vegetal – Prohibición relativa a los piensos – Rumiante.



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