Forage conservation and the problem of methane emission

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It is commonly accepted that one of the pre-requirements for high productivity in dairy farming in the developed regions of the temperate climate zone is the introduction and utilisation of efficient methods of forage conservation. The proportion of conserved forages have significantly increased in relation to the total yearly feed production, and feed quality has markedly improved over the last 50 years.

In Central and Northern Europe as well as in some parts of North America, this was achieved by replacing hay by silage and by using improved technologies of ensiling grasses and legumes. The spread of growing silage maize in cooler regions has also brought further progress.

Competitive situation

Today, there is even competition between different silage sources and grassed pasture, which formerly had been considered superior in terms of quality and costs. Dairy herds with an average milk yield of 8,000kg per cow per year are kept indoors throughout the year and fed on silage as a sole roughage source as this seems to be the only way to meet their very demanding requirements.

From a historical perspective, forage conservation has served one fundamental function – to ensure adequate nutrition of animals in seasons with limited plant growth. There are hardly any regions on the globe in which fresh pasture feed is available throughout the year at a constant volume and quality. Differences are seen between summer and winter or between wet and dry seasons. Animal production, on the other hand, is a continuous process that requires a constant supply of feed in terms of quantity and quality.

Animals do have requirements for maintenance and only feed intake exceeding this will lead in performance. Each day, on which the genetically and physiologically determined performance potential is not fully used due to insufficient nutrition, will ultimately result in losses in productivity.

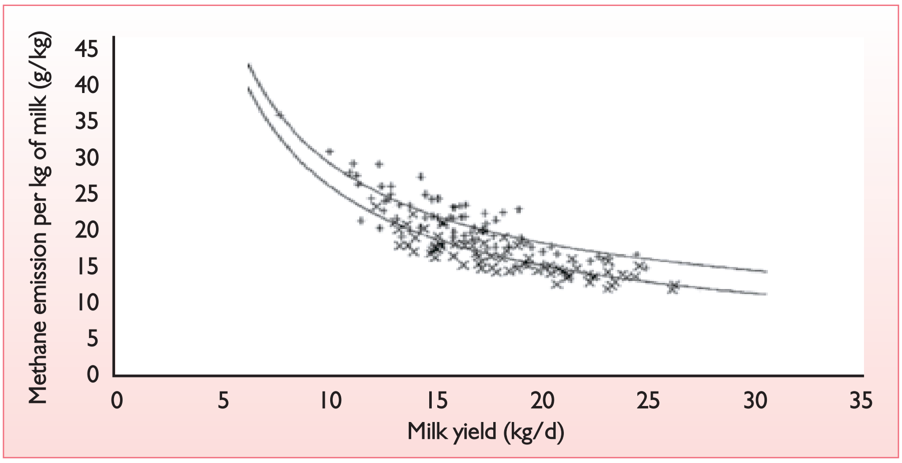

Fig. 1. Methane emission per kg of produced milk as affected by performance level (adapted from Kirchgeßner et. al., 1995).

Thus, forage conservation resolves the discrepancy between continuity in feed demand and discontinuity in vegetation. It therefore ensures the supply of feed based on demand throughout the year.

Moreover, only the conservation of forages enables the determination of optimal quality which would otherwise change during the course of the plant production cycle. This makes it possible to fully exploit the performance potential of animals throughout the year. Therefore, we must conclude that forage conservation and storage are essential issues.

However, public funding for research in forage conservation has dramatically declined during the last decades in many European countries although there is still a lot to do. Institutes of a high international reputation have been closed, and in others drastic staff reductions have been made. This has resulted in a loss of experience and existing knowledge is not being passed on to the next generation.

However, there are still research needs in forage conservation even in developed countries. In this regard it is worth noting that the frequently occurring, serious problems with food hygiene in the globalised world are often caused by hygienic problem of fed silages. Even more important is the need for improvements in emerging nations and developing countries. In these countries the low level in animal performance is often caused by shortages of suitable technologies for forage conservation and therefore a too low extent of storage of feed.

On the other hand, there has been enormous financial support for research projects on methane emissions from ruminants in numerous institutes across the globe. Beside carbon dioxide, methane is known to be the most relevant trace gas regarding climate change and contributes to the greenhouse effect. Its emissions should possibly be limited in the interest of limiting global warming.

Raised awareness

Although methane emissions by ruminants and its potential consequences have been widely known for some time the public, and thereby politicians, seem to have become aware of it only during the last few years. Questions have arisen as to how much methane is produced by ruminants, if this emission can be reduced, and if not, can we still afford to keep cattle, sheep and goats?

However, on the basis of numerous experimental data, which have been available for decades, it is already possible to take a scientifically sound standpoint on this

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topic. The formation of methane is an undesired but unavoidable special characteristic of the ruminant's digestive system. Methane production results in energy loss. On average, 7-9% of ingested gross energy is lost.

Trials have frequently been conducted which aimed at reducing ruminal methanogenesis by special feed additives or by diet formulation. As far as feed additives are concerned (ionophores like monensin), it has been shown that their effects are limited to the first days of administration and that thereafter methane emission soon reached pre-trial level.

New ideas, approaches and concepts for the control of rumen fermentation by chemical additives or bacterial additives still remains largely a matter of speculation.

As of yet, no results from animal trials supporting these hypotheses have been published that showed a sustainable reduction in methane emission by additives of any type that do not affect animal health or performance. Thus, a solution of the problem by using feed additives is not expected in the near future. The possibilities to influence methane emissions by diet formulation can be evaluated by using regression equations describing the relationship between nutrients and methane formation.

The evaluation of the most comprehensive data collection (337 metabolic trials in cattle using 3-12 animals per diet, five days balance period and about 1,500 data sets) resulted in the following multiple regression equation (Jentsch et al 2009):

$$m = 1.32\,x_1 - 0.56\,x_2 + 1.68\,x_3 + 2.78\,x_4$$
$$r^2 = 0.858$$

where m is the methane energy [J] and x_1 to x_4 are the apparent digestible nutrient fractions [g]: x_1 crude protein, x_2 crude fat, x_3 starch + sugar (≈ NFC) and x_4 N-free organic residue (≈ NDF). It is obvious that the content of cell wall substances (NDF), which are typical for diets for ruminants, has the biggest impact on methane formation.

Rations containing high non-fibre carbohydrates (NFC) concentration require high inclusion rates of grain and are therefore not a viable option. The same data sets were used to describe the relationship between dry matter intake by cattle and their methane production (Piatkowski et al 2010):

$$M = 32.76 - 0.384\,x \qquad r^2 = 0.224$$

where M is the methane weight [g/kg DM] and x the feed intake [DM g/kg live weight].

Taking into consideration typical feed intake figures, methane emissions by different cattle categories can be calculated as well as methane emission as a function of milk yield (Table 1). It can be concluded therefore that, regardless of how and where on our globe ruminants are kept and fed, at least 2.1-2.6% of the ingested DM is converted into methane, and emitted. Increasing performance leads to reduced emission per kg ingested DM and per kg milk produced. Cattle which do not perform due to insufficient feed supply take in low amounts of feed and consequently emit low amounts of methane per animal and day. But these methane emissions are not only unproductive, they are also extremely high (2.8%), if related to ingested DM.

This is the range which covers the magnitude of methane emissions from a given number of cattle and their consumption of plant biomass. Simultaneously, this suggests the limits within which emission can be influenced. More possibilities are not available, and will not become available in the near future. Therefore, one is tempted to con-

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Performance	Methane g/kg DM intake	Methane g/kg Milk
Dairy cows		
Maintenance	28.3	
4,000kg milk/year	24.8	29.5
6,000kg milk/year	23.0	22.0
8,000kg milk/year	21.8	17.4
10,000kg milk/year	20.7	14.6
Heifers:		
200-300kg	25.7	
300-400kg	24.7	

Table 1. Methane emission from cattle (Piatkowski et al., 2010).

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clude that the number of cattle, as well as the number of sheep and goats for which the same relationships and emission rates per kg ingested DM are applicable, should be drastically reduced. To consume less food of animal origin, for the sake of the earth's climate, is currently a real request announced in public. Particularly for food products from ruminants is this request entirely unrealistic.

Apart from the fact that the population in emerging or developing countries cannot be denied higher consumption of animal products as a consequence of increasing living standard, the vast portion of agriculturally exploitable land in the world is grassland.

	World		Brazil	
	Area (Million ha)	Proportion (%)	Area (Million ha)	Proportion (%)
Arable land	1381	28	61	23
Permanent crop	146	3	8	3
Pastures	3357	69	196	74
Total agricultural area	4884	100	265	100

Table 2. Grassland as proportion of the total agricultural area. (FAO Statistical Yearbook 2010).

Data presented in Table 2 (taken from the Statistical Yearbook of the FAO) show that two thirds of this are pastures. In Brazil, for example, even about 75% of the total land which is utilisable for agricultural purposes is grassland.

Naturally, the vast acreage of grassland is less productive than arable land. However, its yield cannot be abandoned, today, or in the future in prospect of further increasing world population. Grass can only contribute to feeding mankind by its utilisation by ruminants. Therefore, maintaining a similar cattle number as we have today can hardly be avoided in the future.

Data from statistical publications of the FAO are summarised in Table 3 and show cattle and buffalo numbers in the world and present countries in which at least 50 million animal of this category are already kept.

Also, during the last decade a further increase in cattle numbers could be observed. The least that should be achieved is to stop this trend. The increasing demand for food of animal origin which is caused by the steady growth of the world's population can and must be met by improving animal performance. Concurrently, this is the only realistic way of reducing methane emission per kg product. An even better aim would be to increase performance to such an extent that the number of ruminants and the amount of methane emitted by them could be reduced.

It can be concluded from Fig. 1, and also from data presented in Table 1, that the biggest effect can be achieved by increasing nowadays low performance levels, whereas the contribution to further reducing emissions can be neglected at already high milk yields in high performance animals.

Among countries having very big ruminant populations, and especially in developing countries, there are many with extremely low performance level in animal production and, thus, high potential for performance increases, which would ultimately lead to significant reductions in methane emissions. One of the most effective measures that can be taken for improvements is the implementation of an efficient feed store management. Consequently, the development and implementation of improved technologies for feed conservation, which are adapted to country-specific climatic and socio-economic conditions, becomes an important task of general climate policy.

Further challenges to forage conservation have arisen during the last few years by the increasing use of agriculturally produced plant biomass for energy production. Both, the production of bioethanol and of biogas are continuous biological processes, which, in analogy to animal production, require storage of plant biomass.

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As far as moist grains are concerned, the energy saving preservation technology of anaerobic storage needs to be taken into consideration. If whole plant maize, maize stover, whole plant cereals, biomass from grasses and legumes as well as sugar beet and possibly also sugarcane in future are addressed for production of biogas, conservation by making silage is unavoidable.

Only as silage can forages be used as substratum for biogas production. In addition to the necessity to make these materials storable, plant biomass also for this utilisation needs to be produced at a defined and constant quality. Fermentation in the silo can be considered, at least to a certain degree, the first phase of the whole process of biogas production, which subsequently continues in the fermenter until the fermentable organic matter is fully degraded to methane and carbon dioxide. Quality requirements of silages are similar to those for animal feeding, but not identical in all quality traits.

Production of electricity, heat and fuels from biomass is desired in the future to significantly contribute to the overall production of renewable energies in order to replace fossil sources, thereby relieving the atmosphere of carbon dioxide formed from them. Forage conservation must, and can, bear its crucial share to climate-neutral energy production by providing suitably prepared plant biomass on demand. Also for this purpose must forage conservation be carried out at a larger scale in the future, and the best technologies for that must be developed.

Countries	Cattle and buffaloes (Million heads)		
	1999-2001	2007	2009
India	286	280	279
Brazil	171	201	206
China	125	105	116
USA	98	97	95
Pakistan	45	59	63
Argentina	49	51	51
Ethiopia	35	45	51
World	1479	1540	1571

Table 3. Number of big ruminants (FAO Statistical Yearbook 2010).

Conclusions

Forage conservation in general, and silage production in particular, is an extremely important topic of high priority. Sufficient feeding of the world's growing human population in all regions requires the best possible productive use of agricultural land resources, the reduction of losses of grown biomass and its highly efficient utilisation.

This holds true for all regions of the world, but in emerging countries there are huge possibilities for increasing productivity, which still have not been turned into reality. In many developing countries, efficient subsistence farming structures must be set up which are adapted to the socio-economic conditions. All this is not possible without keeping ruminants. How many animals are needed and how much climate-damaging methane is emitted depends on the performance level of the animals, which, in turn, is affected by the quality of feed management.

A novel challenge is posed by the increasing use of plant biomass as a renewable energy source and the demand for substratum supply. Low-loss conservation and subsequent storage of biomass is crucial.

Consequently, forage production and conservation must be increased and improved by employing suitable technologies. Further research needs to be carried out on silage production. This applies particularly to tropical and subtropical regions, in which silage production has not been used to the extent possible, and needed respectively.

An international exchange of opinions and experiences in forage conservation is useful, but the direct transfer of technologies from temperate climates seems limited. Solutions leading to their broad use under practical conditions must be developed for specific conditions and countries. This ultimately creates the demand for systematic research and extension programs on forage conservation and their financial support. ■

References are available from the authors on request