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Making a decision-support system for dairy farmers usable throughout Europe: the challenge of feed evaluation

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Introduction

As part of the EU research project Sustainable Organic and Low Input Dairying (SOLID; www.solidairy.eu), a decision-support system called SOLID-DSS is currently being developed. SOLID-DSS is meant for strategic use on organic and low input dairy farms, which are usually characterized by their efforts to minimize external inputs, mainly feed and fertilizer, and to maximize the utilization of grassland, especially pasture. By simulating different management options on the farm and evaluating them with regard to the risk of feed shortages, SOLID-DSS shall offer support for strategic management decisions and help balance forage supply and demand. For ration planning on larger time scales, a linear optimization routine is implemented, which combines data from plant growth models with the herd's requirements. As SOLID-DSS shall be usable in many European countries, the existence of several different systems of feed evaluation and nutrient requirements in Europe poses a challenge. Although the plant growth models used in SOLID-DSS are expected to be applicable in large parts of Europe, the parameters of feed quality they supply are limited. Therefore, the feed evaluation, which should be based on data supplied by the plant growth models in order to fully profit from the dynamic plant modelling, represents a constraint for the whole diet model in SOLID-DSS. Hereafter, our chain of thought regarding the challenge mentioned and the solutions we have found so far will be laid out.

Feed quality parameters supplied by the plant growth models

The growth of selected arable crops will be modelled with an extended JavaScript port of MONICA (Nendel *et al.*, 2011); a dynamic soil and generic crop growth model (see https://github.com/zalf-lsa/monica-js). As MONICA does not include an elaborated grassland and pasture model, the crop model of the Sustainable Grazing Systems (SGS) Pasture Model (Johnson *et al.*, 2008) will be implemented as well. The SGS Pasture Model covers pure grass leys, pure legume leys and grass–legume mixtures. Apart from the quantity of feed dry matter available in all given time periods throughout the year, the plant growth models also supply data on feed quality. Currently, the range of feed quality parameters include the contents of nitrogen, soluble carbohydrates (sugars) and cell wall (NDF), and the digestibility of the organic matter.

European systems of feed evaluation and nutrient requirements

Throughout Europe, several different systems for calculating the nutrient requirements of dairy cattle are used, and most of them rely on their own system of feed evaluation. Among those with the most widespread use are the French (Agabriel, 2010), the British (Thomas, 2004) and the Nordic (Volden, 2011) system, and the American National Research Council (NRC, 2001) and Cornell Net Carbohydrate and Protein System (Russell *et al.*, 1992) are valued as well. Efforts to harmonize European feedstuff evaluation have not been successful so far, and most farmers and consultants seem reluctant to use a system of feedstuff evaluation and nutrient requirements other than the one established in their countries. With regard to SOLID-DSS, using only one system to characterize feeds and calculate requirements would have been the simplest option, but as criticism could be expected on the choice of system, which could potentially hinder the acceptance of SOLID-DSS, we decided to explore the idea of offering several different systems. As the French (Agabriel, 2010) and the British (Thomas, 2004) systems are among those with the highest prevalence, these two were an obvious choice. In addition, the German (Society of Nutrition Physiology (GfE), 2001) and the Finnish (MTT, 2006) systems will also be included in the prototype version of SOLID-DSS in order to provide a wider range of choices. Feed intake will be estimated according to GrazeIn (Faverdin *et al.*, 2011),

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regardless of how the nutrient requirements are calculated. As SOLID-DSS will only consider the energy and protein requirements of dairy cattle (no mineral requirements), the crucial points of interest are the energy and protein evaluation of feeds in the four systems mentioned above.

Energy evaluation

In the United Kingdom (Thomas, 2004) and in Finland (MTT, 2006), feed energy is expressed as metabolizable energy (ME in MJ), whereas in Germany (GfE, 2001) and France (Agabriel, 2010) net energy is used, with the units being net energy for lactation (NEL in MJ) in Germany and feed unit (unité fourragère lait, UFL) in France, respectively. The British Feed into Milk system argues that the digestibility of forage is the main source of variation in energy; therefore, the only parameter needed to calculate both British and Finnish ME is the digestible organic matter in feed dry matter. The digestibility of organic matter will be supplied by the plant growth models, but the ash content of the feed, which is needed to relate the digestibility to the dry matter, will not. Therefore, the ash content will have to be assumed based on data from feed tables, but apart from that the calculation of British and Finnish ME is entirely possible based on output from the plant growth models.

In Germany and France, calculation of the net energy value of a feed requires numerous steps of calculation, including the calculations of gross energy and ME, which are mainly based on proximate analysis of the feed according to the Weender Analysis. For German NEL, the content of CP and the contents and digestibilities of organic matter, ether extracts and crude fibre are needed. For the calculation of French UFL, information on the type of feed and (if applicable) its conservation is needed, as well as its contents of ash, CP and crude fibre and the digestibility of organic matter. Out of these parameters, the CP content (calculated from nitrogen content) and the digestibility of organic matter will be supplied by the plant growth models, and an assumed ash content (see above) will be used for calculating the content of organic matter. The parameters not supplied by the plant growth models will have to be assumed based on data from feed tables (content of ether extracts and digestibility of crude fibre) or will be calculated (content of crude fibre from NDF content and digestibility of ether extracts according to MTT, 2006).

To summarize, even though some assumption and additional calculations are necessary, the calculation of British, Finnish, German and French feed energy values mainly based on output from the plant growth models is feasible. If so desired, we could, therefore, express the energy balances, which will result from the diets produced by the diet model in SOLID-DSS, in country-specific energy units.

Protein evaluation

In the British (Thomas, 2004) and Finnish (MTT, 2006) protein systems, the feed protein value is expressed as metabolizable protein (MP in g). The French (Agabriel, 2010) true protein (proteines digestibles dans l'intestin, PDI in g) corresponds to MP, whereas in Germany (GfE, 2001) the unit utilizable CP at the duodenum (uCP in g) is used. Although the protein systems differ in terminology and methods, they all agree that the protein value of a feed is defined by the degradability of its protein, the amino acid contents and digestibilities of the feed protein and the fermentability of its carbohydrates in the rumen, which drives the microbial protein synthesis. Protein degradation in the rumen is estimated with the nylon bag method in the British and French protein systems, whereas the Finnish MP system relies on information mainly from *in vivo* experiments. The microbial protein yield is estimated based on ATP yield in the United Kingdom, whereas in France and Finland it is estimated as a fixed amount based on fermented organic matter in the rumen. The German uCP system differs from the others as it does not predict protein degradation and microbial protein yield separately. Instead, it estimates the sum of ruminally undegraded protein and microbial protein present at the duodenum using regression equations based on experiments with fistulated cows (Lebzien and Voigt, 1999).

To the best of our knowledge, there is no plant growth model currently available that can supply parameters of protein degradation and microbial protein yield. The only protein parameter commonly supplied is the nitrogen content of the feed, which can be translated into CP content using a constant coefficient of $6.25 \times N$. Regarding the energy supply for microbial protein synthesis in the rumen, the plant growth models used in SOLID-DSS supply the digestibility of organic matter, and, as outlined above, we found that the energy value of feeds can be expressed according to four different systems of feed evaluation. The British MP system includes a limited feed table, and its reliance on *in situ* (feed and protein degradation) and *in vitro* (ATP yield) methods make it unsuitable for use in SOLID-DSS at the moment. The French PDI system, on the other hand, offers extensive feed tables, which supply all necessary information. However, the implemented plant growth models are one of the major strengths of SOLID-DSS, therefore, we strive to base feedstuff evaluation on plant growth model output as much as possible. For using the Finnish MP system, only the effective protein degradability would have to be assumed based on data from the feed tables, so protein evaluation according to MTT (2006) would be possible.

German uCP are estimated using one of the 12 different equations differing in their input parameters, of which equation (1a) only requires the ME and CP contents of the feed (Lebzien and Voigt, 1999), which the plant growth models in SOLID-DSS can supply. The comparative simplicity of the uCP system, mainly its assumption of a constant degradability of all dietary protein (except urea), has repeatedly been subject to criticism. However, Ettle and Schwarz (2001) found that the uCP system predicted milk protein yield equally well and in the case of fresh forage even better than the more sophisticated Dutch protein system. Schwab *et al.* (2005) used a data set from eight Finnish production experiments to compare the protein systems from United Kingdom, France, Germany, Denmark, Finland and the United States (NRC), and found that the German uCP system accurately predicted the differences in MP supply between diets and the milk protein yield of cows. In another comparison of the Finnish, German and NRC system using data from 13 US production experiments, the performance of the uCP system was even called 'excellent' (Schwab *et al*., 2005).

To summarize, the German uCP system has the same conceptual basis as other protein systems, but assumes a constant degradability of dietary protein, and therefore evaluation of the protein value of feeds is much simpler and therefore feasible based on output from the SOLID-DSS plant growth models. As there is evidence that the German uCP system performs equally well or even better than more sophisticated protein systems, we decided to use only the German uCP system in the prototype version of SOLID-DSS. Consequently, information on protein balances resulting from the diets produced by the diet model in SOLID-DSS can only be given in relative terms (e.g. 10% oversupply with protein).

Conclusions

Energy evaluation of feeds according to the British, French, Finnish and German systems of feed evaluation was found to be feasible based on output from the plant growth models used in SOLID-DSS, except for some minor assumptions. For the protein evaluation of feeds, only the German uCP system will be used for the first version of SOLID-DSS, because protein evaluation of feeds according to the uCP system is possible without any assumptions. For the future of SOLID-DSS, the implementation of protein systems other than the German is possible, as long as the necessary parameters can be supplied by the plant growth models.

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Further information

The LiveM International Livestock Modelling and Research Colloquium was hosted by the Basque Centre for Climate Change (BC3) at the Maritime Museum in Bilbao, Spain between the 14 and 16 October 2014. LiveM is the livestock and grassland modelling theme of the EU knowledge hub Modelling European Agriculture with Climate Change for Food Security (MACSUR). The MACSUR project is a pilot knowledge hub started by FACCE-JPI in 2012. It provides an opportunity to explore the role and potential of multidisciplinary networking structures to address complex regional and global issues. More information on MACSUR and the LiveM theme can be found at www.macsur.eu, with PDFs of slides from conference presentations available through the conference website http://www.livem2014bilbao.com/.

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