Efficient Cow – Estimation of feed intake for efficiency traits using on-farm recorded data.

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EFFICIENT COW − ESTIMATION OF FEED INTAKE FOR EFFICIENCY TRAITS USING ON-FARM RECORDED DATA

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ABSTRACT

Increasing efficiency is necessary to cope with scarce resources and higher costs especially for energy and concentrate. The Federation of Austrian Cattle Breeders (ZAR) started the project "Efficient Cow" in 2013 to evaluate efficiency traits in cattle breeding under Austrian conditions. Data of approximately 5400 cows, i.e. 3100 Fleckvieh (dual purpose Simmental), 1300 Brown Swiss, 1000 Holstein kept on 167 farms were recorded over a whole year. Feed intake was predicted by a model considering animal and ration specific parameters. The observation of the individual feeding information considering the variety of feeding systems and ration compositions was the biggest challenge. A novel data encoding system for ration components was established to reflect different on-farm feeding situations correctly and to ensure a successful and structured further processing for intake prediction. A total of 1960 different rations could be reduced to 16 different ration types and therefore calculation methods depending on the way ration components were offered, namely mixed together, separately or without known amount or proportion in diet like pasture.

Key words: cattle breeding, efficiency, phenotypes, dairy cows, feed intake prediction, on-farm data collection

1 INTRODUCTION

Increasing efficiency is necessary to cope with scarce resources and higher prices especially for energy and concentrate, but also when prices for products are under pressure. Because total costs in dairy production consist of feed costs for more than 50 % (de Haas *et al.*, 2014), feed efficiency is an important part to increase herd profitability. Feed efficiency is however only one aspect of efficiency. Efficiency should also include aspects of health, fertility and longevity. Over the past decades milk production and therefore live weight of dairy cows has increased (Krogmeier, 2009). Heavier cows have to produce more milk to be as efficient as smaller cows. But feed intake capacity did not develop in parallel with milk production. Therefore higher concentrate diets are necessary to meet demand. Steinwidder (2009) calculated a proportion of concentrate of 18 % for a cow with 550 kg but of 27 % for a cow with 850 kg. In case of insufficient nutrient supply, a negative energy balance especially in early lactation leads to a higher risk for diseases and infertility (Martens, 2012).

Results of a survey among Austrian dairy farmers 2012 (Steininger *et al.*, 2012) revealed their rising interest in health and efficiency traits. Beside this the discussion about greenhouse gas emissions was another reason for

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starting the project “Efficient Cow” in Austria in 2012, headed by the Federation of Austrian Cattle Breeders (ZAR).

As the possibilities of recording efficiency related traits in research herds are limited in Austria, the project aims at on-farm recording. Aside from that a reasonable number of animals also enables genetic analyses of the new defined efficiency traits. Because of the lack of individual measurements of feed intake, novel strategies for recording and estimating feed intake had to be developed considering the big variety of diet composition and feeding systems in Austria. Furthermore information of characteristics of diets and of feed and nutrient intake is essential for modelling greenhouse gas emissions.

This paper focuses on the methodical way from data collection to the feed intake prediction models.

2 MATERIAL AND METHODS

2.1 DATA COLLECTION

The Federation of Austrian Cattle Breeders (ZAR) initiated the project “Efficient Cow” at the end of the year 2012 with a one-year data collection in 2014. The objective of “Efficient Cow” was to develop efficiency parameters in cattle breeding considering Austrian circumstances. Efficiency combines already used traits like milk, beef, health and functional traits, and other traits which are relevant for feed efficiency. Therefore beside data, which are included in the routine performance recording, additional parameters like live weight, body measurements and parameters describing diets, feed quality and health were collected at each performance testing during the whole year 2014. Data of nearly 5400 cows (3100 Fleckvieh – dual purpose Simmental, 1300 Brown Swiss, 1000 Holstein) kept on 167 farms were collected. Farms were selected to cover the diverse production environments in Austria ranging from mountainous regions to intensive farms in climatically favourable regions. Despite this, the herd size with 32.6 cows is approximately twice as high as the Austrian average (Steininger *et al.*, 2015).

2.2 FEEDING SYSTEMS AND PARAMETERS

The observation of the individual feeding information considering different feeding systems and ration compositions was the biggest challenge. The information on ration composition needs to be structured in such way that it can be used for feed intake estimation with the prediction model no. 1 of Gruber *et al.* (2004). This equation considers, inter alia, the influence of forage quality (NEL_{Forage}, MJ NEL kg DM^{-1}) and of the total amount of concentrate (kg cow^{-1}) in the diet.

The amount of concentrate can be measured relatively accurately, if it is offered separately per automation, but less precisely if it was offered manually. Despite these inaccuracies, the separately fed amounts of concentrate were assumed to be fed without residues. The challenge was to find a method to calculate the concentrate intake, if a total mixed ration (TMR) or partial mixed ration (PMR) is fed. The amount of concentrate depends on the intake of mixed ration, but at the same time the intake of mixed ration depends on the total amount of concentrate. So methods to calculate concentrate supplementation had to be developed depending on the type of ration (TMR, PMR, separately supplemented concentrate SEP) and special characteristics.

Another challenge was to integrate farmers’ statements that a little amount of forage had been fed separately to the main (mixed) ration. For example, 1 kg hay was scattered over the TMR (80 % forage, 20 % concentrate) to motivate cows to eat more. This separately offered component must not be integrated into the remaining mixed ration if calculating feed intake. Strictly speaking, this ration is not a TMR anymore, but the way to calculate feed intake is equal to a TMR combined with a special formula to integrate the separately fed forage. Therefore in this study such a ration is still understood as TMR but with a special calculation module. So the amount of the separated hay is assumed to be known like the separately fed concentrate, but the intake of the TMR is depending on individual parameters like milk yield and live weight and is therefore estimated with the feed intake model considering the hay. These separately fed amounts of a ration component are defined as “fixed” components. Fixed components are assumed to be eaten without feed residues, so that the accurate amount is not an unknown variable. Contrary to these fixed parts of ration, feed intake of the 80 % forage and 20 % concentrate of the TMR is not known, but it can be estimated because of the known composition of the mixed ration. The ratio of forage intake of the fixed components to the total forage intake makes it possible to weight and mathematically express NEL_{Forage} now considering both, mixed and fixed forage components in the total ration.

The third challenge was to handle components, where no amount or proportion was recorded. For example the diet consists of pasture with supplementation of preserved food. The offered and known amounts of preserved food are too much, as that they can be assumed to be eaten fix. The ratio of pasture to preserved food is unknown. This constellation of ration components led to the introduction of “*ad lib*”-components. Here the ratio of offered mixed forage components to the potential mixed forage intake was used to assume a ratio for NEL_{Forage} calculation. Therefore the data had to be expressed in kg cow^{-1}.

So the ration components were partitioned into mixed, fixed and ad lib components, which describe the component type. Each main ration type (TMR, PMR and SEP) can thus be modified with a fixed and/or ad lib forage component. The simplest diet consists only of mixed forage components. Overall, 16 different combinations of the component types mixed forage, mixed concentrate, fixed forage and fixed concentrate and ad lib forage were defined. So a standard TMR only consists of mixed forage and mixed concentrate, the PMR has additionally fixed concentrate, and a SEP only mixed forage and fixed concentrate. The encoding of the ration components according their component type reflects the different feeding systems and diets of the dairy cows in a transparent way.

To ensure high data quality, completed forms of the farmers had to be checked across different form types and dates within each farm before finally entering data into the database. Implausibilities were clarified directly with the farmers or the person responsible for the on-farm data collection.

The following data had to be recorded:

- start date of ration and used concentrate mixtures
- three feeding groups: lactation, additional high lactation if necessary and dry cows
- ration type: TMR, PMR and SEP
- component type: mixed, fixed and ad lib components
- category of forage considering botanical origin (grassland, legumes, forage maize, straw), conservation (hay, silage, fresh) and number of mowing
- concentrate composition (proportion of barley, wheat, …)
- commercial compound feed and nutrient content
- feed samples for analysis of forage in the laboratory for feed analyses of the chamber of agriculture in Austria
- individual amount of concentrates fed separately from forage (kg/cow and day)

2.3 ESTIMATION OF FEED INTAKE

The individual daily feed intake estimation was conducted in cooperation with the Austrian Agricultural Research and Education Centre Raumberg-Gumpenstein.

As individual feed intake was impossible to measure on-farm, the total feed intake (DMI) prediction model no. 1 for separated concentrate supplementation of Gruber *et al.* (2004) was used for calculation:

$$DMI = 3.878 + Country * Breed + Parity + Day\ in\ Milk + b_{BW} * BW + b_{Milk} * Milk + b_{Concentrate} * Concentrate + 0.858 * NEL_{Forage}$$

This empirical model considers the fixed effects of breed and country, management level, parity, stage of lactation depending on day in milk and the regression coefficient for the energy content of forage (NEL_{Forage}). Depending on the day in milk the regression coefficients for body weight (b_{BW}), milk performance (b_{Milk}) and for amount of concentrate ($b_{Concentrate}$) have to be calculated. This shows the influence of the stage of lactation on milk performance, live weight and on forage substitution (Gruber *et al.*, 2004).

The original model no. 1 only covers diets, where concentrate is supplemented separately from forage. For calculating with a TMR and PMR, the input parameters concentrate amount had to be expressed mathematically depending on feed intake, concentrate proportion in mixed ration (mixed concentrate) and separately fed fixed concentrate. If the ration additionally had a fixed forage component, NEL_{Forage} had to be expressed according the characteristics of the ration type.

The adaption of the chosen equation was preferred to take advantage of the high coefficient of determination (R^2 = 86.7 %) and the low residual standard deviation (RSD = 1.32 kg DM) compared to prediction model no. 5 for TMR (R^2 = 83.5 %, RSD = 1.46 kg DM) (Gruber *et al.*, 2004). Jensen *et al.* (2015) evaluated the up-to-date feed intake models of NRC (2001), of Volden *et al.* (2011), TDMI-Index (Huhtanen *et al.*, 2011), Wageningen-DCM (Zom *et al.*, 2012a, 2012b) and TMR-Model no. 5 (Gruber *et al.*, 2004) for dry matter intake by dairy cows fed TMR and found the Gruber model to be the most accurate one.

3 RESULTS AND DISCUSSION

Approximately 1960 different diets were recorded, 1932 were potentially relevant for intake estimation, but under consideration of data quality, only 1890 could finally be used for further processing. On the whole 1260 forage analyses were available for calculating the nutrients of 570 forage components without analyses. This method ensures site- and management adapted assumptions of nutrients instead of using tabulated data. Approximately 2280 different feeds including 1830 forage components and 438 concentrates as well as compound feeds were needed for describing the diets. Finally the

1960 diets could be reduced to 16 different types of rations due to the possible combinations of the component types. For each ration type another mathematical adaption of feed intake model had to be developed. These numbers show the diversity and complexity of feeding systems and ration compositions of the present investigation. For this reason a prediction model had to be chosen, which reflects ration composition and forage quality parameters besides animal individual factors like parity, stage of lactation, live weight and milk yield.

Furthermore estimation should be individual and as accurate as possible to enable calculation of efficiency traits. The feed intake equation by NRC (2001) considers similar animal related criteria, but not feed-specific parameters like forage quality or concentrate level. The feed intake model by Volden *et al.* (2011) belongs to a semi-mechanistic feeding model and represents a fill-factor system. It combines the feed intake capacity, which is determined by live weight, stage of lactation, parity, breed and milk yield with the filling effect of the feed. Similarly the Wageningen-Dairy Cow Model (DCM) (Zom *et al.*, 2012a, 2012b) works, but without considering milk yield and live weight for feed intake capacity. The TDMI-Index (total dry matter intake) system (Huhtanen *et al.*, 2011) combines the silage-DMI (SDMI)-Index and the concentrate-DMI (CDMI)-Index. While the SDMI-Index pictures the forage quality including parameters like digestibility and fermentation quality, the CDMI-Index considers amount and composition of concentrate.

Model no. 5 for TMR (Gruber *et al.*, 2004) includes concentrate proportion of mixed ration instead of amount like in equation no. 1 for separate concentrate supplementation. Although Jensen *et al.* (2015) found the model no. 5 for TMR (Gruber *et al.*, 2004) to be the most accurate one compared with the before mentioned up-to-date models, it was not chosen for estimating TMR in this project. Instead model no. 1 for separated concentrate supplementation was applied, and modified for PMR and TMR. Because a specific prediction model for PMR of Gruber *et al.* (2004) does not exist, model no. 1 had to be adapted to it anyway. A PMR is a more general type of a TMR, because of the additional separately fed concentrate. Furthermore using the same equation only with adaptions to the ration type guarantees a uniform estimation of feed intake.

Another advantage of the models by Gruber *et al.* (2004) is the special consideration of the influence of stage of lactation on the regression coefficients for live weight, milk yield and concentrate level. Therefore they vary with day in milk. Thus, the changes of physiological stage from early to late lactation are taken in account, i.e., the change from a catabolic to an anabolic metabolism (Korver, 1982). Forage substitution by concentrate is higher at the end of lactation, and the influence of live weight decreases due to gained body fat (Gruber *et al.*, 2004).

4 CONCLUSIONS

The recording of novel phenotypes from about 5300 cows on 167 farms, especially of feeding information per individual, was a big challenge. The feeding data base had to be designed using the experiences with the survey forms of the first half year of data collection. Without this experience revealing the diversity of feeding systems of the 167 farms, ration compositions and the way to describe this could not have been considered for data entering and feed intake estimation.

Rations had to be partitioned into mixed, fixed and ad lib components, which reflect the way the feed was offered like fixed concentrate with automation or manually, mixed concentrate together with mixed forage components in a TMR or PMR. Ad lib components had to be inserted into the data encoding system, because mostly the amount or proportion of pasture was not known.

This system of encoding ration components was the only possibility, to make the variety of diets and feeding systems handy for feed intake estimation. The estimation model had to be adapted to the 16 cases of ration types, which results from the 16 possible combinations of different categories of component

Without this novel system of handling the on-farm information, the estimation of feed intake and calculation of mostly individual nutrient contents in finally individual total rations would not have been possible with data observed on-farm.

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6 REFERENCES

De Haas, Y., Pryce, J. E., Berry, D. P., Veerkamp, R. F. (2014). Genetic and genomic solutions to improve feed efficiency and reduce environmental impact of dairy cattle. In *Proceedings of 10th Word Congress on Genetics Applied to Livestock Production, Vancouver 2014*. Retrieved from https://event.crowdcompass.com/wcgalp2014/activity/krfCbPBxzB

Gruber, L., Schwarz, F. J., Erdin, D., Fischer, B., Spiekers, H., Steingass, H., Meyer, U., *et al.* (2004). Vorhersage der Futteraufnahme von Milchkühen – Datenbasis von 10 Forschungs- und Universitätsinstituten Deutschlands, Österreichs und der Schweiz. In *Qualitätssicherung in landwirtschaftlichen Produktionssystemen. 116. VDLUFA-Kongress, Rostock 2004* (pp. 484–504). Speyer: VDLUA-Verlag.

Huhtanen, P., Rinne, M., Mäntysaari, P., Nousiainen, J. (2011). Integration of the effects of animal and dietary factors on total dry matter intake of dairy cows fed silage-based diets. *Animal, 5*, 691–702.

Jensen, L. M., Nielsen, N. I., Nadeau, E., Markussen, B., Nørgaard, P. (2015). Evaluation of five models predicting feed intake by dairy cows fed total mixed rations. *Livestock Science, 176*, 91–103.

Korver, S. (1982). *Feed intake and production in dairy breeds dependent on the ration. Doctoral thesis*. Wageningen: Landbouwhogeschool te Wageningen, 139 p.

Krogmeier, D. (2009). Zusammenhänge zwischen Nutzungsdauer und Körpergröße unter besonderer Berücksichtigung des Stallsystemes bei Braunvieh und Fleckvieh. *Züchtungskunde, 81*, 328–340.

Martens, H. (2012). Die Milchkuh – Wenn die Leistung zur Last wird! In *Milchproduktion – Status quo und Anpassung an zukünftige Herausforderungen. 39. Viehwirtschaftliche Fachtagung, Irdning 2012, Bericht LFZ Raumberg-Gumpenstein* (pp. 35–42). Irdning: AREC Raumberg-Gumpenstein.

NRC (National Research Council). (2001). *Nutrient requirements of dairy cattle. 7th edition*. Washington D. C.: National Academy Press.

Steininger, F., Fuerst-Waltl B., Pfeiffer, C., Fuerst, C., Schwarzenbacher, H., Egger-Danner, C. (2012). Participatory development of breeding goals in Austrian dairy cattle. *Acta Agriculturae Slovenica*, Supplement 3, 143–147.

Steininger, F., Fuerst, C., Fuerst-Waltl, B., Gruber, L., Mayerhofer, M., Ledinek, M., Weissensteiner, R., *et al.* (2015). Efficient Cow – Strategies for on-farm collecting of phenotypes for efficiency traits. ICAR Technical Workshop, Krakow 2015. *ICAR Technical Series* 19, 167–173.

Steinwidder, A. (2009). Modellrechnungen zum Einfluss der Lebendmasse von Milchkühen auf Futtereffizienz und Kraftfutterbedarf. In *Werte – Wege – Wirkungen: Biolandbau im Spannungsfeld zwischen Ernährungssicherung, Markt und Klimawandel. Beiträge zur 10. Wissenschaftstagung Ökologischer Landbau, Zürich, 11.–13. Februar 2009. Vol. 2 – Tierhaltung, Agrarpolitik und Betriebswirtschaft, Märkte und Lebensmittel* (pp. 30–33). Berlin: Verlag Dr. Köster.

Volden, H., Nielsen, N. I., Åkerlind, M., Larsen, M., Havrevoll, Ø., Rygh, A. J. (2011). Prediction of voluntary feed intake. In H. Volden (Ed.), *The Nordic Feed Evaluation System. EAAP Publication No. 130* (pp. 113–126). Wageningen: Wageningen Academic Publishers.

Zom, R. L. G., Andre, G., Van Vuuren, A. M. (2012a). Development of a model for the prediction of feed intake by dairy cows: 1. Prediction of feed intake. *Livestock Science, 143*, 43–57.

Zom, R. L. G., Andre, G., Van Vuuren, A. M. (2012b). Development of a model for the prediction of feed intake by dairy cows: 2. Evaluation of prediction accuracy. *Livestock Science, 143*, 58–69.