Validation of behavioural-based models to estimate pasture herbage dry matter intake of dairy cows

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Abstract

The individual pasture herbage dry matter intake (PHDMI) of dairy cows can be important for efficient and sustainable milk production. Depending on the PHDMI, supplementation can be implemented indoors to cover the animal's requirements, and pasture management can be improved. In a previous study, different behavioural-based models were developed to estimate the PHDMI of Holstein dairy cows. In our study, these models were validated with an independent dataset (n=72) from different experiments. One observation is the 7-day average of the PHDMI of a dairy cow and the corresponding 7-day average of the predictors. Behavioural data were collected with a noseband sensor (RumiWatch). The PHDMI was measured using the n-alkane double marker technique. Based on these measurements, the weekly values of the measured PHDMI and the estimated PHDMI of the models were compared. The mean bias was generally low, ranging from −0.1 to 0.81 kg dry matter (DM) with a standard deviation around 1.9 kg. However, there was little agreement for individual cows' PHDMI, with a concordance correlation coefficient of 0.33 at best. Therefore, it is concluded that the behavioural models predict a good herd average of daily PHDMI, but not for an individual dairy cow.

Keywords: behaviour, grazing, decision support, grazing management, herbage intake

Introduction

Decision support for farmers to optimise their management is the key aim of digital technologies applied on farms. In dairy production systems, especially in confinement systems, many sensors are already applied, whereas the application of sensors for grazing animals is still limited. In particular, the main aim of estimating the individual PHDMI of dairy cows to optimise grazing management and supplementation schemes remains challenging (Tedeschi *et al*., 2019). There are various approaches to improving estimations by farmers, which are either based on visual estimations or expertise. In the literature, there are studies using mathematical models, mainly regression models, to estimate PHDMI based on behavioural parameters or production values, such as milk yield or energy requirements (Perdana-Decker *et al*., 2023; Rombach *et al*., 2019; Schori *et al*., 2020).

Estimating PHDMI values close to the real intake of dairy cows is one reason for developing a decision-support tool. Finding solutions to visualise or integrate this information into useful applications is another important element in implementing more digital solutions at the farm level. Therefore, an attempt was made to visualise the individual PHDMI of dairy cows using the Intake Analyser software, either based on a model including exclusively behavioural parameters or a model including additional production variables, such as milk lactose content and body weight. Behavioural parameters were measured using the noseband sensor RumiWatch.

The aim of this study was to validate the developed behavioural-based and production-based models, which were integrated into the Intake Analyser software. An independent reference dataset gathered under temperate pasture-based dairy production conditions was used for this purpose.

Materials and methods

Six grazing trials on multispecies temperate pastures were conducted in western Switzerland at the organic farm Ferme Ecole de Sorens during the vegetation periods of 2018 and 2019. The results of these trials were used as a reference dataset to validate the PHDMI models. Each trial consisted of 13–14 dairy cows. A total of 38 individual dairy cows were used, including 22 Holstein and 16 Swiss Fleckvieh cows. These cows were either primi- or multiparous, with a mean body weight of 603±45 kg, a mean age of 45±7 months, and mean days in milk of 154±32 at the beginning of the trials. In addition to grazed herbage, the cows were fed a bait feed (pelleted dried whole maize plant), an energy-rich concentrate and a mineral mixture. On average, the cows consumed 0.7 kg DM of supplements day^{-1} (ranging from 0 to 3.25 kg DM). Each cow was equipped with a RumiWatch halter (Itin + Hoch GmbH, Liestal, Switzerland), a noseband sensor to record daily behavioural parameters, which was previously validated under grazing conditions (Rombach *et al.*, 2018). Finally, 72 seven-day measurements of the PHDMI (mean PHDMI=13.9±1.6 kg DM day^{-1}) were taken using the n-alkane double indicator technique (Rombach *et al.*, 2019) and used as a reference intake. Behavioural sensor data were processed using the RumiWatch Converter V.7.3.36 (Itin + Hoch, Bennwil, Switzerland) and were averaged first per day and second by the daily pasture access time to provide an average weekly dataset. As pasture access times differed between the four trials in June 2018 and 2019 and the two trials in September 2018, the one-hour summaries from 5 am to 7 am and 12 pm to 6 pm (June) or 4 pm to 6 pm (September) were excluded to calculate behavioural parameters limited to cows being on pasture. Two models estimating PHDMI were evaluated against the reference dataset. The behavioural-based model with eight predictors (Schori *et al.*, 2020), referred to as S5, and one production-focused model by Rombach *et al.* (2019), referred to as WSB3, were evaluated. Both models were integrated into the Intake Analyser software V.1.1.7.0. (Itin + Hoch) to visualise individual PDHMI based on the RumiWatch sensor data (S5) and body weight and milk lactose content with behavioural data (WSB3).

Results and discussion

The mean bias of PHDMI and its standard deviation estimated with the S5 are −0.13±1.95 kg DM day^{-1}, compared to 0.81±1.85 kg DM day^{-1} with the WSB3. This result demonstrated a slight underestimation of the behavioural-based model compared to the reference intake, whereas the WSB3 model, including production parameters, overestimates the PHDMI of individual cows. However, the root mean square error (RMSE) of S5 with 1.93 kg DM day^{-1} is comparable to 1.94 kg DM day^{-1}for WSB3. Also, the relative prediction error (RPE) is similar, with 14.0% for S5 and 14.4% for WSB3. These results are comparable to the development datasets of Schori *et al.* (2019), who found an *RPE* of around 15% for S5. Rombach *et al.* (2019) obtained an *RPE* of 11–13%, even though the development dataset of WSB3 included a higher level of supplementation with roughage and concentrates. However, the correlation of the estimated PHDMI at the individual cow level with the reference intake based on S5 and WSB3 was very low, with an R^2 of 0.11 for S5 and 0.06 for WSB3, and a concordance correlation coefficient (CCC) of 0.33 for S5 and 0.24 for WSB3. This demonstrates a low level of precision in estimating the individual PHDMI, but considering the mean bias of both models, the estimations at the herd level were acceptable. The R^2 and *CCC* may be improved using a more versatile dataset covering the whole range of PHDMI values, from low to high herbage intakes. In our dataset, the measured PHDMI ranged from 11.4 to 18.2 kg DM day^{-1}. Including both models in the Intake Analyser software will help farmers understand herd intake dynamics and quantify the differences of individual cows, even though the numerical values per individual cows are not accurately estimated. Furthermore, behavioural-based models perform similar to, or even better than, production-based models. This gives scope to use these models in the future, not only with lactating cows but perhaps also with non-lactating cows. The inclusion of production parameters or body weight may hamper farmers from using these intake estimation models, as those values are not frequently recorded and sometimes not precisely measured, whereas the behavioural parameters might be easier to measure with advanced sensor technologies.

Conclusion

The estimation models, either behavioural- or production-based, were evaluated and appear to be valid for estimating mean herd PHDMI, but seem only moderately suitable for estimating individual PHDMI. Furthermore, behavioural-based models perform similarly to or even better than production-based models. A larger validation dataset with more values in the range of 2–12 kg PHDMI per day may increase the correlation coefficient of the models.

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References

Perdana-Decker S., Velasco E., Werner J. and Dickhoefer U. (2023) On-farm evaluation of models to predict herbage intake of dairy cows grazing temperate semi-natural grasslands. *Animal* 17(5), 100806.

Rombach M., Münger A., Niederhauser J., Südekum K.-H. and Schori F. (2018) Evaluation and validation of an automatic jaw movement recorder (RumiWatch) for ingestive and rumination behaviors of dairy cows during grazing and supplementation. *Journal of Dairy Science* 101(3), 2463–2475.

Rombach M., Südekum K.-H., Münger A. and Schori F. (2019) Herbage dry matter intake estimation of grazing dairy cows based on animal, behavioral, environmental, and feed variables. *Journal of Dairy Science* 102(4), 2985–2999.

Schori F., Rombach M., Münger A. and Südekum K.-H. (2020) Individual herbage intake estimation of grazing dairy cows, based only on behavioural characteristics. *Grassland Science in Europe* 25, 351–353.

Tedeschi L.O., Molle G., Menendez H.M., Cannas A. and Fonseca M.A. (2019) The assessment of supplementation requirements of grazing ruminants using nutrition models. *Translational Animal Science* 3(2), 811–828.