Isotopic N fractionation as a biomarker of nitrogen use efficiency by ruminants: A meta-analysis

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Abstract
We evaluated the potential to use the naturally occurring isotopic N fractionation between plasma or milk of ruminants and their diet ($\Delta^{15}N_{animal\text{-}diet}$) to predict between-animal variation in N use efficiency (NUE), as well as assessed the main mechanisms by which $\Delta^{15}N_{animal\text{-}diet}$ is related to NUE under common feeding conditions. Individual values for NUE (n = 217) and $\Delta^{15}N_{animal\text{-}diet}$ (n = 274) from 11 published experiments were analyzed by meta- analysis. All dietary treatments were characterized according to the newly-updated French feeding system. The $\Delta^{15}N_{animal\text{-}diet}$ reflects between-animal variation in NUE and underlying mechanisms by which $\Delta^{15}N_{animal\text{-}diet}$ is related to NUE across diets are at both the metabolic and rumen levels.

Keywords: Feed efficiency, ^{15}N, Individual variability

Introduction

Nitrogen use efficiency (**NUE**; nitrogen gain or milk nitrogen yield/N intake) is an important component of animal feed efficiency. A promising biomarker for NUE is based on the phenomenon of N isotopic fractionation (**$\Delta^{15}N_{animal\text{-}diet}$**; the difference between animals and their diet in natural abundance of ^{15}N). This approach may have potential to discriminate individuals fed the same diet, but with different N partitioning. A number of studies over the last 5 years have evaluated this new biomarker for NUE in ruminants, but its potential to reflect individual variation has not been yet assessed. The objectives of this study were to i) assess the potential of $\Delta^{15}N_{animal\text{-}diet}$ to predict variation in NUE at the individual level and ii) disentangle the main mechanisms by which this biomarker is related to NUE.

Material and methods

Eight publications (Cabrita *et al.*, 2014; Cantalapiedra-Hijar *et al.*, 2015, 2016; Cheng *et al.*, 2011, 2013a, 2013b, 2014, 2015) reporting NUE and $\Delta^{15}N_{animal\text{-}diet}$ values in ruminants were analyzed. There were 11 separate experiments, 42 treatments and individual values for NUE (n = 217) and $\Delta^{15}N_{animal\text{-}diet}$ (n_{milk} = 145 and n_{plasma}= 129). Meta-analysis was performed by GLM (Minitab v14), adopting both between-experiment and within-treatment approaches. Dietary treatments were characterized using the newly updated INRA feeding system and the main determinants of NUE were analyzed by partial least square (PLS) regression (XLStat v2015.2.02). Independent variables were: rumen protein balance (**RPB**; g/kg DM), rumen degradable protein (**RDP**, g/kg DM), efficiency of microbial protein synthesis according to either available energy (**EMPS_E**, g/g rumen fermentable OM) or available protein (**EMPS_N**, g /g RDP), the metabolizable protein (**MP**) to net energy ratio (**MP/NE**, g MP/MJ), the digestive efficiency of N use (**DENU**, g MP/g crude protein), the efficiency of MP utilization for either production (**EMPU_prod**, g protein in milk or gain/g MP) or the sum of production and non-productive (Sauvant et al., 2015) losses (**EMPU_absol,** g/g MP).

Results and discussion

A between-experiment quadratic relationship ($P<0.001$; r2 = 0.78; RSE = 0.63) between individual $\Delta^{15}N$ and NUE values was identified (Fig. 1), indicating that $\Delta^{15}N_{animal\text{-}diet}$ progressively reaches maximum values as NUE approaches zero. The within-treatment linear relationship ($P<0.001$; Fig. 1) between individual $\Delta^{15}N$ and NUE values was significant highlights the potential of this isotopic biomarker to predict between-animal variation in NUE. The proposed PLS model made good predictions of variation in $\Delta^{15}N$ resulting from dietary characteristics (Q2 = 0.88; RMSE = 0.37) and contributed to explain most of the variability in observed values ($R^2(Y) = 0.91$).

The most important variables explaining $\Delta^{15}N$ variation were related to the metabolic efficiency of N use (VIP = 1.10-1.19) but there were also relationships with rumen and digestive N use (VIP = 0.85-1.00).

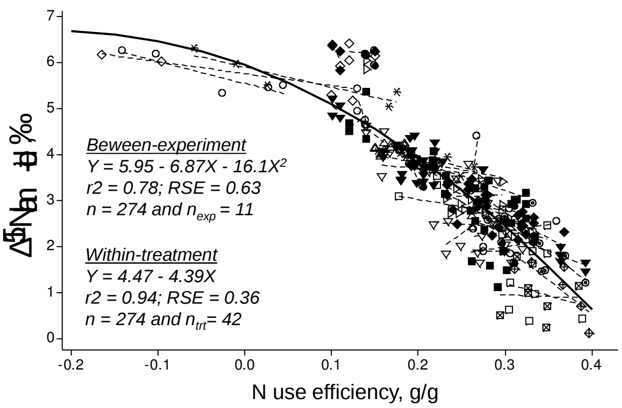

Figure 1. Between-experiment ( ) and within-treatment (--) relationships between individual $\Delta^{15}N_{animal\text{-}diet}$ and NUE.

References

Cabrita, A.R.J., A.J.M. Fonseca and R. J. Dewhurst, 2014. Short communication: Relationship between the efficiency of utilization of feed nitrogen and ^{15}N enrichment in casein from lactating dairy cows. Journal of Dairy Science 97(11): 7225-7229.

Cantalapiedra-Hijar, G., I. Ortigues-Marty, B. Sepchat, J. Agabriel, J.F. Huneau and H. Fouillet, 2015. Diet–animal fractionation of nitrogen stable isotopes reflects the efficiency of nitrogen assimilation in ruminants. British Journal of Nutrition, 113(07): 1158-1169.

Cantalapiedra-Hijar, G., H. Fouillet, J.F. Huneau, A. Fanchone, M. Doreau, P. Nozière and I. Ortigues-Marty, 2016. Relationship between efficiency of nitrogen utilization and isotopic nitrogen fractionation in dairy cows: contribution of digestion v. metabolism? Animal 10(2): 221-229.

Cheng, L., E.J. Kim, R.J. Merry and R.J. Dewhurst, 2011. Nitrogen partitioning and isotopic fractionation in dairy cows consuming diets based on a range of contrasting forages. Journal of Dairy Science 94(4): 2031-2041.

Cheng, L., A.J. Sheahan, S.J. Gibbs, A.G. Rius, J.K Kay, S. Meier, G.R. Edwards, R.J. Dewhurst and J.R. Roche, 2013a. Technical note: nitrogen isotopic fractionation can be used to predict nitrogen-use efficiency in dairy cows fed temperate pasture. Journal of Animal Science 91(12): 5785-5788.

Cheng, L., A.M. Nicol, R.J. Dewhurst and G.R. Edwards, 2013b. The effects of dietary nitrogen to water-soluble carbohydrate ratio on isotopic fractionation and partitioning of nitrogen in non-lactating sheep. Animal 7(08): 1274-1279.

Cheng, L., S.L. Woodward, R.J. Dewhurst, H. Zhou and G.R. Edwards, 2014. Nitrogen partitioning, energy use efficiency and isotopic fractionation measurements from cows differing in genetic merit fed low-quality pasture in late lactation. Animal Production Science 54(10): 1651-1656.

Cheng, L., G.R. Edwards, R.J. Dewhurst, A.M. Nicol and D. Pacheco, 2015. The effect of dietary water soluble carbohydrate to nitrogen ratio on nitrogen partitioning and isotopic fractionation of lactating goats offered a high-nitrogen diet. Animal, 1-7.

Sauvant, D. G. Cantalapiedra-Hijar, L. Delaby, P. Faverdin and P. Nozière, 2015. Updating protein requirements in ruminants and determination of the responses of lactating females to metabolisable protein supply. INRA Productions Animales 28(5): 347-367.