Prediction of the in vivo organic matter digestibility of cereal-legume intercrops silages

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Abstract

There is an increasing interest in using cereal-legume intercrops mixtures in ruminant production systems to assist forage self-sufficiency and climate change adaptation. Available data on the energy value of the cereal-legume silages are limited due to a lack of *in vivo* organic matter digestibility (OMD) measurements and the potential vast number of mixtures used in practice. The objective of this work was to study the relationships between *in vivo* OMD and some chemical and enzymatic parameters of different cereal-legume silages in order to identify a potential predictor for the OMD. Data from four trials with sheep carried out on the experimental farms of INRA Le Pin-au-Haras (France) and Agroscope, Posieux (Switzerland) were used. The cereals in the mixtures were oat, wheat or triticale, and the legumes were pea and vetch. Mixtures were harvested at two stages of growth. Significant relationships were observed between OMD and crude protein content, legume proportion and pepsine-cellulase digestibility (PCD). The best model to predict OMD used PCD (R^2=0.71). Additional data with other mixtures and legume proportions are required to confirm this result, but PCD would enable the prediction of *in vivo* OMD of cereal-legume silages with good precision.

Keywords: *in vivo* digestibility, cereal-legume silages, prediction

Introduction

Intercropping cereals with legumes is developing in French ruminant production systems to permit forage self-sufficiency, reduce nitrogen fertilizers and for climate change adaptation. Silages produced from a mixture of whole-crop cereal and whole-crop legume are likely to have a higher concentration of crude protein (CP) and digestibility than cereal monoculture or moderate quality grass silage (Adesogan *et al.*, 2002; Adesogan *et al.*, 2004; Pursiainen and Tori, 2006). However, the feed value of these silages is still not well-known due to a lack of *in vivo* measurements and the potential vast number of mixtures used. Few references are available in the Feed Tables from European countries. In France, no predictive equation is available to estimate the *in vivo* organic matter digestibility (OMD) for these silages from common predictors such as *in vitro* digestibility or the chemical composition of silages. The *in vivo* OMD of the cereal-legume silages is, therefore, estimated using predictive equations developed for other forages such as grass, legume or maize silages (INRA, 2007), which is certainly not adapted to these forages. The objective of this work was to study the statistical relationships between *in vivo* OMD and a few chemical and enzymatic characteristics of cereal-legume silages in order to find a method to estimate OMD suitable for these forages.

Materials and methods

Data (n=16) from *in vivo* experimentations carried out between 2010 and 2014 in two experimental farms: Le-Pin-au-Haras, INRA, France (two digestion trials) and Posieux, Agroscope, Switzerland (two digestion trials), were used. In the INRA first trial, the silages tested were field pea (*Pisum sativum* L.) + common vetch (*Vicia sativa* L.) with the cereal wheat (*Triticum aestivum* L.), beardless triticale (*X Triticosecale)* or bearded triticale at the seed ratio of respectively 17, 20 and 220 seeds m^{-2}. These three silages were harvested

at two stages of growth: early (about 20% dry matter, DM, at harvest) and late (about 30% DM at harvest). In the INRA second trial, the silages were field pea + wheat harvested at the two same stages of growth. Silages tested at Agroscope were field pea + triticale + oat (*Avena Sativa* L.) harvested at late stage of growth (cereals at dough-milky stage); silages differed in the pea to cereals seed ratio (Arrigo, 2014; Arrigo *et al.,* 2015). The different silages were ensiled without additives except for three silages that received Kofasil Bale® (Addocon, Germany) and after wilting for mixtures harvested at an early stage.

In all experiments, *in vivo* OMD for each silage was measured on 4 to 6 male castrated sheep. The botanical composition of the forages was determined at harvest. Silages were analysed for ash, CP content (Dumas method, Rapid N Cube, Elementar Analysensystem GmbH), neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents using an Ankom fiber analyser (Ankom Technology, Macedon, NY, USA) with heat-stable amylase. Pepsin-cellulase digestibility (PCD expressed as g kg^{-1} DM) of the forages was determined according to Aufrère and Michalet-Doreau (1983). The statistical relationships (linear and stepwise regressions) between OMD and the chemical composition, legume proportion and PCD of the silages were tested with the Minitab® statistical software.

Results and discussion

Descriptive statistics on chemical composition and digestibility of the silages are shown in Table 1. The DM content was on average 309 g kg^{-1}, the silages from Switzerland being dryer (351 g kg^{-1} DM) than silages from France (273 g kg^{-1} DM). The CP content varied from 54 to 161 g kg^{-1} DM and ADF content from 302 to 398 g kg^{-1} DM. On average, the *in vivo* OMD was 638±40.3 g kg^{-1} OM, which was consistent with previous *in vivo* OMD measurements on cereal-legume silages (Adesogan *et al.*, 2002). The legume proportion at harvest was low (0.17 on average), only 5 mixtures had a legume proportion higher than 0.20.

The CP content ($P<0.001$, $R^2=0.70$) and OMD ($P=0.02$, $R^2=0.27$) of silages increased with the increase in the legume proportion in the mixture, whereas the NDF content decreased. The ADF content did not differ with the legume proportion in the mixture. On average, the CP content and OMD were slightly higher for the silages harvested at early stage (108 g kg^{-1} DM and 666 g kg^{-1} OM) than for the silages harvested at late stage (91 g kg^{-1} DM and 628 g kg^{-1} OM).

Significant relationships were obtained between *in vivo* OMD and the legume proportion in the mixture, CP content (Equation 1) and PCD (Equation 2). The type of mixture and the *in vivo* data origin (France vs Switzerland) were not significant.

$$\text{OMD (g kg}^{-1}\text{ OM)} = 1.039^{(P=0.001)} \times \text{CP (g kg}^{-1}\text{ DM)} + 539^{(P<0.001)} \quad (1)$$

with $n_{data} = 16$, RMSE = 26.7 and $R^2 = 0.56$.

Table 1. Chemical composition and digestibility of the cereal-legume silages ($n = 16$) used to establish a predictive equation of the *in vivo* organic matter digestibility.

	Mean	S.D.	Min	Max
Legume proportion	0.17	0.24	0	1
Dry matter (DM), g kg^{-1}	309	62.1	207	423
Crude protein, g kg^{-1} DM	95	29.8	54	161
Neutral detergent fibre, g kg^{-1} DM	533	46.2	441	649
Acid detergent fibre, g kg^{-1} DM	329	23.5	302	398
Ash, g kg^{-1} DM	66	16.8	47	104
Pepsine-cellulase digestibility, g kg^{-1} DM	545	62.7	421	662
In vivo organic matter digestibility, g kg^{-1} OM	638	40.3	583	715

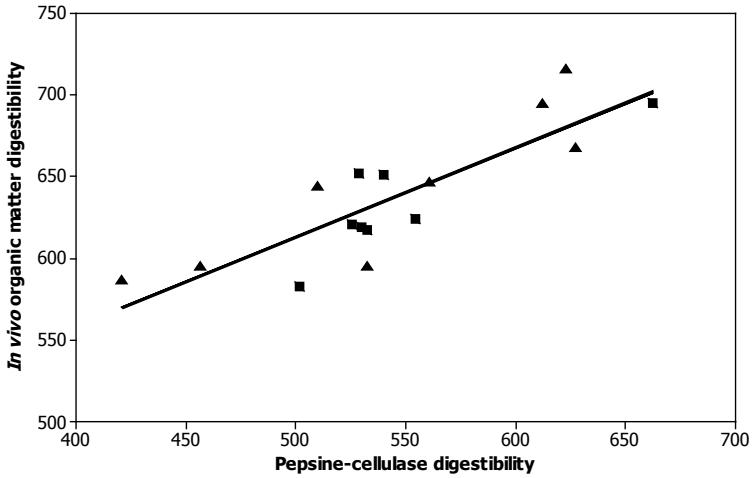

Figure 1. The relationship between *in vivo* organic matter digestibility (g kg^{-1} OM) and pepsine-cellulase digestibility (g kg^{-1} DM) of cereal-legume silages (▲: data from INRA, France; ■: data from Agroscope, Switzerland).

$$OMD\ (g\,kg^{-1}\ OM) = 0.548^{(P<0.001)} \times PCD\ (g\,kg^{-1}\ DM) + 339^{(P<0.001)} \quad (2)$$

with $n_{data} = 16$, RMSE = 21.6 and R^2=0.71.

The best model to estimate OMD used PCD as the predictive variable (Figure 1). Inclusion of CP content or legume proportion in Equation 2 did not improve the prediction.

The RMSE of the Equation 2 was low (21.6 g kg^{-1}). However, the R^2 is slightly lower than R^2 of equations previously developed for others forages (0.71 vs 0.83 for grass or legume silages and 0.78 for grass; INRA, 2007). These differences could be explained by the limited number of data in this study, or by a different pattern of seasonal OMD changes for cereal-legume crops compared with grass or legume crops.

Conclusions

The equation using the *in vitro* PCD as predictor allows an estimation of the OMD of cereal-legume silages samples with a good precision. However, additional data with others cereal and legume species and different legume to cereal proportions, especially silages performed from crops with greater proportion of legume (>0.35) are required to confirm these results.

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