Dry matter intake and milk yield prediction equations based on animal factors and fecal specters using NIRS: preliminary results[1]

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Introduction

Dairy production in Vietnam and Reunion Island is a recent and in expansion activity. The domestic milk production in both countries meets only 20 and 30% of local demands corresponding to 158 000 and 24 000 tons / year, respectively (Bony et al., 2005, Luthi et al., 2006).

Vietnam and Reunion Island are identically characterized by tropical and temperate climates. They offer a large diversity of feed systems to dairy production due to its altitudinal gradients topography. Rations of dairy cattle are thus much diversified and its quality varies strongly according to regions and seasons. The major problem of the diet that affects animal performance is inadequate or unbalanced in protein and energy (Bony et al., 2003). It is hence necessary to determine the quality of feed for the formulation of diets to prevent underfeeding or overfeeding of nutrients and to promote efficient nutrient use. One of the most important nutrients determining feed quality is the nature of protein and its degradation by the animal digestion system.

The evaluation of the diet quality is generally limited by a large number of samples which require a high and expensive technique. However, a new approach to determine the diet quality by using feces parameters have been developing in the recent years (Awuma, 2003; Boval et al., 2004; Fanchone et al., 2007; Strang, 2004). Feces consist on residues of ingested feed and some other components of microbial and animal origin. Boval (2004) also suggested that the chemical composition of the undigested residues of forage diets are likely to be closely correlated with the chemical composition of herbage ingested, so that feces should contain information about the characteristics of the diet (Coleman et al., 1995).

This study aimed to characterize fiber combined protein (FCP) in feed and feces to evaluate diet quality and animal performance. Some prediction models will be developed using animal factor and feces parameters such as FCP. Animal parameters are considered as factors determining animal requirements and FCP in faces is considered as factors concerning diet quality. Both of these factors are easily collected in the field and due to the relatively low cost of NIRS analysis, developed prediction models would be applicable.

Materials and Methods

Animal and diet

In order to acquire such a large variation which represent the real situation of dairy production in both countries, the study was conducted at 25 representative farms in Reunion Island (France) and in Vietnam. Two hundred cows were selected randomly from diverse breeds (Holstein Friesian, Jersey, Brown Swiss, crossed breeds) of difference lactation numbers (1^{st} to 11^{th}). Similarly, body weight (BW), milk performance and lactation stage of these animals were strongly ranging from 252 to 784 kg BW, 3.5 to 38.2 kg of milk and 1 to 49 weeks of lactation. Rations offered to the animals also differed robustly from countries, feeding systems and farm scales.

Data collection

Body weight (BW), week of lactation (WOL), milk yield (MY) and milk compositions (fat, protein) were monthly recorded. Body weight was indirectly determined by a thoracic perimeter. Milk was weighed and sampled for chemical analysis twice daily at the milking times. Forage intake was determined by using the total amount of feed divided by number of animal consuming the feed while concentrate intake was individually determined. The refusal determination was realized in the next morning. The same procedure was applied in both Reunion and Vietnam and 1 100 individual data was collected.

Sample collection and preparation

Feed in the diet were recorded and sampled as fresh weight at the feeding position. Faecal samples were collected directly in the rectum in the next morning of the day when feed intake was determined. They were then dried in a force-air oven at 70 °C for 48 h to determine dry matter (DM). After that, all samples were grounded into 1 mm screen using CYCLOTEC (FOSS, 1093 Sample Mill) and stored in closed plastic boxes at a room temperature before chemical and NIRS analyses.

Reference analyses

Crude protein (CP), Neutral Detergent Insoluble Protein (NDF-IP; which represents the unavailable protein bound to the NDF fraction), Acid Detergent Insoluble Protein (ADF-

[1] PhD thesis on "Qualification of fiber combined protein of feed and its digestive utilization by dairy cattle in the tropical regions (Reunion Island – Vietnam) using near infrared reflectance spectroscopy"

IP; unavailable protein bound to the ADF fraction) was determined by CN-2000 elementary analyzer (LECO, 2002). NDF, ADF were determined by AOAC procedure (van Soest, 1991). Duplicate measurements were made for each procedure and sample. When the coefficient of variation between duplicates accounted for more than 5%, the analyses was repeated.

NIRS analysis

Each sample was scanned twice in a near infrared region (1100 – 2500 nm) of 2 nm intervals with NIRSsystem5000. Mean of each sample's specters was calculated and then WinISI III software was used for calibration and validation in order to develop NIRS prediction equations.

Statistical analysis

All the statistical analysis was performed using SASystem (2000) and Minitab 14 (2003). The statistical models used in this study depend on different sections.

Preliminary results and discussions

Statistics of NIRS prediction equations developed to estimate CP of forages and feces are shown in table 1. The results showed that CP was accurately predicted by NIRS with the highest coefficient of determination (R^2 = 98 and 99%) and low SEC, SEcv (0.38, 0.54 and 0.22, 0.30 %DM, respectively). Statistics of equations predicting NDF-IP, ADF-IP were quite better than those reported from other studies (Hoffman et al., 1999; Valdés et al., 2006). It was thus concluded that NDF-IP and ADF-IP of both forages and feces could be predicted by NIRS.

Table 1. Statistics of NIRS prediction equations developed to estimate protein fractions (% DM)

Constituent	N	Mean	SEC	1-VR	SEcv	R^2 cv
			Forages (n = 51)			
CP	48	14,3	0,38	98	0,54	98
NDF-IP	48	1,5	0,12	91	0,19	91
ADF-IP	47	0,3	0,03	81	0,04	81
			Feces (n = 140)			
CP	140	11,97	0,22	99	0,30	99
ADF-IP	140	0,40	0,03	83	0,04	83

Some other applications of NIRS in term of developing equations to predict animal performance and diet quality were focused in the study. In this synthetic report, only DMI and 4% fat corrected milk (4% FCM) prediction equations were presented (table 2, 3 and 4). The table 2 showed that 78.8% of DMI variation was predicted by NIRS using only faecal specters and its predictive ability (Predicted R^2) for a new observation achieved 76.9%. But the predictive ability increased up to 83.3 and 80.7% for R^2 and predicted R^2 when the equation was added animal factors such as BW, WOL. There have been many studies on developing DMI prediction equations with animal factors and/or diet factor or feces but no study using animal factor and feces in the same equation.

Table 2. Comparison of simple prediction models for DMI (Reunion I. and Vietnam)

Variables	MPE	MSPE	RPE	R^2	Pre_R^2
FECES (NIRS)	1.92	3.67	9.31	78.8	76.9
BW, WOL, FECES	1.69	2.84	8.20	83.3	80.7

MPE: Mean prediction error (kg/d); MSPE: Mean square prediction error (kg^2/d); RPE: Relative prediction error (%) (MPE/observed DMI); R^2: Coefficient of determination (%); Pre.R^2: Predictive R^2 (%)

Figure 1 and table 3 illustrated the accuracy of the new DMI prediction equation. Figure 1 showed the equation fitted 80.6 % of the data. While table 3 showed its highest predictive ability (R^2 = 69.2) and the smallest bias (-0.49 kg/day) compared with other common equations when it was validated with an independent dataset.

Figure 1. Relationships between observed and predicted DMI of a new model

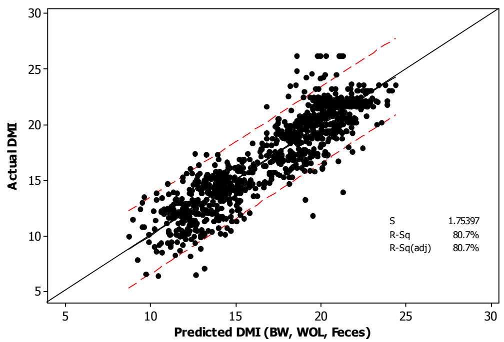


Table 3. Accuracy of new DMI prediction model compared with other models evaluated with an independent dataset

Models	Variables	MPE	MSPE	RPE	Bias	R^2
Sniffen (1985)	BW, 4% FCM	2.45	6.01	14.31	2.39	60.0
Fox (1993)	BW, 4% FCM, DOL,	3.26	10.64	19.04	2.73	29.3
CNCPS 5.0	BW, 4% FCM, WOL,	2.49	6.19	14.55	2.60	58.9
NRC (2001)	BM, 4% FCM, WOL	2.53	6.40	14.78	0.87	57.5
Modified NRC	BM, 4% FCM, WOL	2.52	6.37	14.72	1.19	57.6
New equation	**BW, WOL, FECES**	**2.15**	**4.6**	**12.56**	**-0.49**	**69.2**

MPE: Mean prediction error (kg/d); MSPE: Mean square prediction error (kg^2/d); RPE: Relative prediction error (%) (MPE/observed DMI); Bias: Difference between the observed average measurement and a predictive reference (kg/day); R^2: Coefficient of determination (%); DOL: Day of lactation (d)

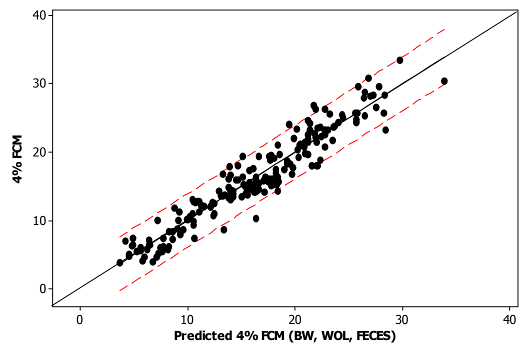
Table 4 and figure 2 illustrated the possibility of NIRS to predict 4% FCM from feces. It is well-known that the diet quality is one of the most important factors affecting milk performance (NRC, 2001).

Table 4. Development of simple prediction models for 4% FCM with average of animal grouped data

Variables	MPE	MSPE	RPE	R^2	Pre_R^2
FECES (NIRS)	4.09	16.73	25.11	67.07	64.48
BW, WOL, FECES	2.43	5.90	15.09	**91.6**	**79.18**

MPE: Mean prediction error (kg/d); MSPE: Mean square prediction error (kg^2/d); RPE: Relative prediction error (%) (MPE/observed DMI); R^2: Coefficient of determination (%); DOL: Day of lactation (d); Pre.R^2: Predictive R^2 (%)

Figure 2. Relationships between observed and predicted 4% FCM of a new model



Otherwise, many studies suggested that the chemical composition of feces contains information about the characteristics of the diet because it is closely correlated with the chemical composition of herbage ingested (Coleman et al., 1995; Boval, 2004). As a result, feces could also contain information about animal performance such as a mentioned 4% FCM. This hypothesis will be demonstrated in the next step of the study.

Perspectives

Preliminary results mentioned above show the potential of feces in term of developing some models to evaluate diet quality and to predict animal performance using NIRS method. In the next step of the study, the characterizing of fiber combined protein (NDF-IP, ADF-IP) and other parameters in feed and feces will be realized to illustrate these hypotheses.

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