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Estimation and validation of total digestible nutrient values of forage and concentrate feedstuffs

Anuraga Jayanegara[1,*], Muhammad Ridla[1], Nahrowi[1] and E B Laconi[1]

[1] Department of Nutrition and Feed Technology, Faculty of Animal Science, Bogor Agricultural University, Bogor 16680, Indonesia

*Corresponding author: anuraga.jayanegara@gmail.com

Abstract. Total digestible nutrient (TDN) values represent utilisable energy contents of feedstuffs, and these are extremely important values in order to provide adequate energy supply for livestock. This study aimed to estimate and validate TDN values of forage and concentrate feedstuffs from their nutrient contents. Nutrient composition data were obtained from BR CORTE database, comprised of 86 forage and 36 concentrate feedstuffs. The data included contents of dry matter (DM), organic matter (OM), ash, neutral detergent fiber (NDF), lignin, non-fiber carbohydrate (NFC), ether extract (EE), crude protein (CP) and TDN. A correlation analysis was conducted among the nutrient composition parameters for forage and concentrate. Data were then randomly divided into two parts, the first part (two-third of data) was used to estimate TDN whereas the second part (one-third) was used to validate the estimated TDN. Estimation of TDN was performed by employing a multiple linear regression method and it was validated by plotting between observed and estimated TDN. Results revealed that TDN in forage was negatively correlated with NDF ($P<0.001$) and lignin ($P<0.05$), but positively correlated with NFC and EE contents (both at $P<0.001$). Such pattern was similarly obtained with that in concentrate. Prediction equations of TDN in forage and concentrate were TDN = 0.479 NDF + 0.704 NFC + 1.594 EE + 0.714 CP and TDN = 0.323 NDF + 0.883 NFC + 1.829 EE + 0.885 CP, respectively. Values of estimated and observed TDN both in forage and concentrate were closely similar. It is concluded that TDN can be accurately estimated from nutrient composition data.

1. Introduction

Energy is an essential factor for all living creatures in order to sustain life including livestock. Provision of energy for livestock is performed through feed and it substantially determines the production level of livestock to provide meat and milk for human consumption. Main nutrients that contribute to energy are carbohydrate (both structural and non-structural carbohydrate), lipid and protein [1]. The energy present in feed is called gross energy (GE) but it does not reflect to which extent the energy is available for livestock. Therefore other energy measures have been developed in order to overcome such weakness such as digestible energy (DE), metabolizable energy (ME) and net energy (NE) [2]. Determination of GE, DE, ME and NE requires a bomb calorimeter. However, this equipment may not be easily available in animal feed laboratories in developing countries like Indonesia.

Another energy system has been developed without using such facility, i.e. total digestible nutrient (TDN). The TDN value represents utilizable energy content of a feedstuff and it is calculated as the sum of digestible carbohydrate + 2.25 × digestible lipid + digestible protein. Indonesia has been using this

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system since a number of decades particularly for feed formulation in order to meet the energy requirement of ruminant livestock [3]. However, most of the TDN values in the country are estimated through a number of equations and seldomly derived through experiments. Unfortunately the available prediction equations apparently have not been validated against the values obtained experimentally. Therefore this study aimed to estimate as well as to validate TDN values of forage and concentrate feedstuffs from their nutrient contents.

2. Materials and methods

Nutrient composition data were obtained from BR CORTE database [4], comprised of 86 forage and 36 concentrate feedstuffs. The data included contents of dry matter (DM), organic matter (OM), ash, neutral detergent fiber (NDF), lignin, non-fiber carbohydrate (NFC), ether extract (EE), crude protein (CP) and TDN. The NFC is calculated as: NFC = OM – (NDF + EE + CP). Summary (mean ± standard deviation) of chemical composition of forage and concentrate used in the database is presented in Table 1.

Table 1. Summary (mean ± standard deviation) of chemical composition (% dry matter) of forage (n = 86) and concentrate (n = 36) used in the database.

Parameter	Forage	Concentrate
Dry matter	34.0 ± 19.8	89.0 ± 3.89
Organic matter	92.1 ± 2.38	94.6 ± 2.45
Ash	7.95 ± 2.38	5.42 ± 2.45
Neutral detergent fiber	67.6 ± 9.80	36.1 ± 18.7
Lignin	6.51 ± 2.42	4.20 ± 3.34
Non-fiber carbohydrate	15.1 ± 9.01	30.2 ± 22.9
Ether extract	2.58 ± 1.78	7.34 ± 9.41
Crude protein	9.52 ± 4.18	26.1 ± 15.4
Total digestible nutrient	54.0 ± 5.65	75.4 ± 20.4

A correlation analysis was conducted among the nutrient composition parameters for forage and concentrate [5]. Significance correlation coefficients were marked with *, ** or *** for $P<0.05$, $P<0.01$ or $P<0.001$, respectively. Data were then randomly divided into two parts, the first part (two-third of data) was used to estimate TDN whereas the second part (one-third) was used to validate the estimated TDN. Estimation of TDN was performed by employing a multiple linear regression method in which the independent variables were carbohydrate (NFC and NDF), lipid (EE) and protein (CP). These variables were chosen as the predictors to TDN since energy is theoretically generated from these components. Validation of the equations was performed by plotting between the observed and estimated TDN.

3. Results and discussion

The NDF content in forage was negatively correlated with NFC, EE and CP ($P<0.001$; Table 2). The TDN in forage was negatively correlated with NDF ($P<0.001$) and lignin ($P<0.05$), but positively correlated with NFC and EE contents (both at $P<0.001$). In concentrate, NDF was positively correlated with lignin ($P<0.01$) but negatively correlated with NFC ($P<0.001$; Table 3). Similar with that in forage, TDN in concentrate was negatively correlated with NDF ($P<0.05$) and lignin ($P<0.01$), but positively correlated with NFC ($P<0.01$) and EE ($P<0.001$).

Prediction equations of TDN in forage and concentrate were TDN = 0.479 NDF + 0.704 NFC + 1.594 EE + 0.714 CP and TDN = 0.323 NDF + 0.883 NFC + 1.829 EE + 0.885 CP, respectively (Table 4). These prediction equations were quite accurate as indicated by the high values of adjusted R^2. The relatively lower NDF coefficient to TDN as compared to those of NFC, EE and CP coefficients indicates its lower contribution to energy available for livestock. This may be related to the negative effect of NDF, particularly lignocellulose component, on ruminal degradation and total tract digestibility [6,7]. Relatively similar coefficients between NFC and CP to estimate TDN confirm the similarity of energetic values between starch and protein [8]. The high EE coefficient to TDN is expected since lipid is widely known to generate much higher energy as compared to starch and protein [9].

Table 2. Correlation coefficient between chemical composition of forage (n = 86).

Item	Ash	NDF	Lignin	NFC	EE	CP	TDN
Ash	1						
NDF	–0.01	1					
Lignin	–0.22*	–0.22*	1				
NFC	–0.46***	–0.62***	0.15	1			
EE	–0.03	–0.45***	0.27*	0.18	1		
CP	0.30**	–0.61***	0.17	0.05	0.30**	1	
TDN	–0.31**	–0.52***	–0.24*	0.68***	0.45***	0.19	1

*, P<0.05; **, P<0.01; ***, P<0.001.
NDF, neutral detergent fiber; NFC, non-fiber carbohydrate; EE, ether extract; CP, crude protein; TDN, total digestible nutrient.

Table 3. Correlation coefficient between chemical composition of concentrate (n = 36).

Item	Ash	NDF	Lignin	NFC	EE	CP	TDN
Ash	1						
NDF	0.27	1					
Lignin	0.27	0.50**	1				
NFC	–0.59***	–0.62***	–0.38*	1			
EE	–0.19	0.01	–0.11	0.06	1		
CP	0.32	–0.14	0.01	–0.60***	–0.15	1	
TDN	–0.49**	–0.37*	–0.44**	0.44**	0.83***	–0.11	1

*, P<0.05; **, P<0.01; ***, P<0.001.
NDF, neutral detergent fiber; NFC, non-fiber carbohydrate; EE, ether extract; CP, crude protein; TDN, total digestible nutrient.

Table 4. Equation for estimating TDN from chemical composition of forage and concentrate.

Feed class	Equation
Forage	TDN = 0.479 NDF + 0.704 NFC + 1.594 EE + 0.714 CP
	(P<0.001, MSE = 17.2, Adj R^2 = 0.994)
Concentrate	TDN = 0.323 NDF + 0.883 NFC + 1.829 EE + 0.885 CP
	(P<0.001, MSE = 21.6, Adj R^2 = 0.996)

TDN, total digestible nutrient; NDF, neutral detergent fiber; NFC, non-fiber carbohydrate; EE, ether extract; CP, crude protein; MSE, mean square error; R^2, coefficient of determination.

Values of estimated and observed TDN both in forage and concentrate were closely similar (Figure 1), indicating the validity of the prediction equations. These equations may therefore be used to accurately estimate TDN contents in forage and concentrate feedstuffs. In case to estimate TDN content of a total mixed ration (TMR), one has to exactly know the proportion of forage to concentrate in order to obtain the TDN value of the ration. For instance, a TMR with forage to concentrate proportion of 60:40, its TDN equation is: $TDN_{TMR} = (0.6 \times TDN_{forage}) + (0.4 \times TDN_{concentrate})$ = 0.417 NDF + 0.776 NFC + 1.688 EE + 0.782 CP.

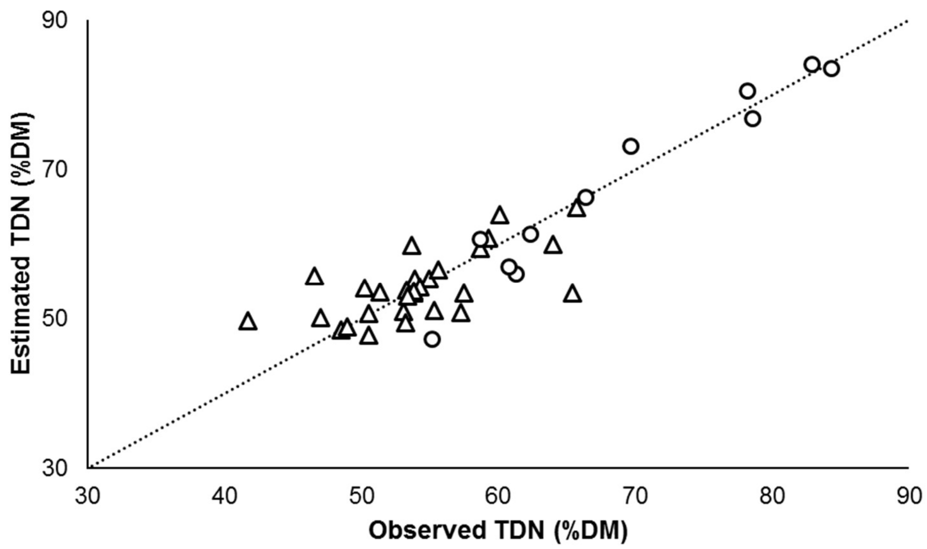

Figure 1. Plot between observed and estimated total digestible nutrient (TDN) content of forage (Δ) and concentrate (o).

4. Conclusion

TDN contents of forage and concentrate diets can be accurately estimated from nutrient composition data. Furthermore, the TDN content of TMR with a certain forage to concentrate proportion can be derived from the prediction equations.

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