DEVELOPMENT AND EVALUATION OF A TROPICAL FEED LIBRARY FOR THE CORNELL NET CARBOHYDRATE AND PROTEIN SYSTEM MODEL

Luís Orlindo Tedeschi[1,3]*; Danny Gene Fox[1]; Alice N. Pell[1]; Dante Pazzanese Duarte Lanna[2,3]; Celso Boin[3]

[1]Dept. of Animal Science, Cornell University, 130 Morrison Hall, Ithaca, NY, 14853.
[2]Depto. de Produção Animal - USP/ESALQ, C.P. 9 - CEP: 13418-900 - Piracicaba, SP.
[3]CNPq Fellow
**Corresponding author <lot1@cornell.edu>*

ABSTRACT: The Cornell Net Carbohydrate and Protein System (CNCPS) model has been increasingly used in tropical regions for dairy and beef production. However, the lack of appropriate characterization of the feeds has restricted its application. The objective of this study was to develop and evaluate a feed library containing feeds commonly used in tropical regions with characteristics needed as inputs for the CNCPS. Feed composition data collected from laboratory databases and from experiments published in scientific journals were used to develop this tropical feed library. The total digestible nutrients (TDN) predicted at 1x intake of maintenance requirement with the CNCPS model agreed with those predicted by the Weiss et al. (1992) equation (r^2 of 92.7%, MSE of 13, and bias of 0.8%) over all feeds. However, the regression r^2 of the tabular TDN values and the TDN predicted by the CNCPS model or with the Weiss equation were much lower (58.1 and 67.5%, respectively). A thorough comparison between observed and predicted TDN was not possible because of insufficient data to characterize the feeds as required by our models. When we used the mean chemical composition values from the literature data, the TDN predicted by our models did not agree with the measured values. We conclude using the TDN values calculated using the Weiss equation and the CNCPS model that are based on the actual chemical composition of the feeds result in energy values that more accurately represent the feeds being used in specific production situations than do the tabular values. Few papers published in Latin America journals that were used in this study reported information need by models such as the CNCPS.
Key words: CNCPS, evaluation, feed library, tropical feeds

DESENVOLVIMENTO E AVALIAÇÃO DE UMA BIBLIOTECA DE ALIMENTOS TROPICAIS PARA O MODELO “SISTEMA DE CARBOIDRATO E PROTEÍNA LÍQUIDOS” DA UNIVERSIDADE DE CORNELL

RESUMO: O uso do Sistema de Carboidrato e Proteina Líquidos da Universidade de Cornell (CNCPS) tanto para produção de leite como carne tem aumentado durante o últimos anos nas regiões tropicais. Entretanto, a falta de uma caracterização adequada de alimentos tem restringido o seu uso corretamente. Esse trabalho teve como objetivo principal o desenvolvimento e a avaliação de uma tabela de composição de alimentos utilizados nas condições tropicais. Os dados da composição desses alimentos foram baseados nas informações necessárias para o uso do modelo CNCPS desenvolvido pela Universidade de Cornell, USA. A composição desses alimentos foi obtida através de análises realizadas em laboratórios e de experimentos publicados em revistas científicas. Os nutrientes digestíveis totais (NDT) estimados através da composição de carboidratos e proteina dos alimentos pela equação de Weiss et al. (1992) e pelo modelo CNCPS foram comparados com os valores da tabela. O NDT estimado ao nível de mantença (1x) com o modelo CNCPS obteve valores próximos aos estimados pela equação de Weiss et al. (1992) (r^2 = 92.7% e bias = 0.8%). Entretanto, o r^2 da regressão entre os valores de NDT da tabela e o estimado pelo CNCPS e por Weiss foram menores (58.1 e 67.5%, respectivamente). Uma comparação completa entre os valores observados e preditos não foi possível devido a falta de caracterização dos alimentos conforme necessário pelos modelos testados. Quando os valores médios de literatura foram utilizados, a correlação entre o NDT estimado e o observado foi muito baixa. Concluímos que os valores de NDT estimados por Weiss e modelo CNCPS fornecem melhores estimativas de NDT do que os valores de tabela. A maioria dos trabalhos publicados que foram avaliados nesse estudo raramente incluíam informações necessárias para modelos como o CNCPS.
Palavras-chave: CNCPS, avaliação, tabela de alimentos, alimentos tropicais

INTRODUCTION

The demand for meat and milk will increase 2.9 and 3.2% annually in the developing world between 1993 and 2020 (Bradford, 1999; Delgado et al., 1999). Improved nutrition is the most important and most feasible way to increase animal productivity to meet this anticipated demand. The development of accurate feed composition information for the tropics that can be used to develop accurate feeding recommendations is extremely important for cattle production to develop feeding systems that optimize use of available forages.

When measured data on the protein and carbohydrate contents of feeds were used, the predictions of the performance of growing steers (Tedeschi, 2001, Chap. 2) and dual-purpose cows (Juarez Lagunes et al., 1999; Lanna et al., 1996) by the Cornell Net Carbohydrate and Protein System (CNCPS) were more accurate than when tabular values were used. The CNCPS model requires an accurate description of the carbohydrate and protein fractions and the rates of digestion of these fractions to obtain the best predictions.

Several feed composition tables have been developed for tropical regions. An extensive feed table was published by McDowell et al. (1974) for feeds commonly used in Latin America. In this publication, only the Weende system components (dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF), ash (Ash), and nitrogen-free extract (NFE)) and some minerals were reported. The total digestible nutrients (TDN), which was derived either from digestion trials or from empirical equations published by Harris et al. (1972), was used to estimate the feed concentration of metabolizable energy (ME) and net energy (NE).

Several short and locally generated feed tables from Latin America have also been published, e.g. Brazil (Quadros et al., 1978; Silva & Silva, 1977), Chile (Hirsch et al., 1974; Pichard & Innocenti, 1987), Colombia (Laredo & Peralta, 1988; Laredo & Peralta, 1990), Costa Rica (Maroto, 1955), and Panama (Rosas et al., 1976).

The Food and Agricultural Organization (FAO) has published (Göhl, 1975; Göhl, 1981) and currently maintains an electronic version[1] of the composition of some tropical feeds. In this collection, only the Weende components, digestibility coefficients, TDN, minerals, and amino acids for some feeds were reported. Similar to the FAO publications, Legel (1984) has described a German tropical feed library, but only proximate analyses (Weende) were reported.

The International Feedstuffs Institute (IFI) has compiled a comprehensive publication containing the composition of feeds from different ecozones (Fonnesbeck et al., 1984). This publication includes prediction of energy values and the Weende components, minerals, vitamins, and amino acids composition of feedstuffs as well as mineral supplements commonly used in animal nutrition.

Tropical feed tables published to date do not contain information on the chemical analyses used to estimate biological value (absorbed energy and protein of feeds) using models that predict TDN from simulated ruminal fermentation based on unique feed characteristics. These fractions are important to be able to more accurately describe feed in each unique production situation.

The objective of this study was to develop a tropical feed library containing chemical composition values needed for the CNCPS model (Fox et al., 2000) to predict feed biological values. A second objective was to evaluate the consistency of the feed composition in this library by comparing TDN values predicted by two different approaches with reported TDN values. The goal is to provide nutritionists with a feed library that can be used in the design and development of more efficient feeding systems in the tropics.

MATERIAL AND METHODS

Organization of the Tropical Feed Library

The data were collected from the following sources to develop the tropical feed library: (1) the feed chemical analysis database of the University of São Paulo Animal Science feed analysis laboratory (Escola Superior de Agricultura "Luiz de Queiroz" – ESALQ/USP, Piracicaba, SP, Brazil) containing feeds analyzed from 1995 to 1997; (2) Brazilian research with animal performance, digestibility trials, feed analysis, and feed degradation rates published in scientific journals (Alvarenga, 1993; Andrade & Andrade, 1982; Andrade et al., 1994; Andrade et al., 1987; Andrade et al., 1990; Araújo & Languidey, 1982; Barbosa et al., 1985; Becker et al., 1995; Becker et al., 1962; Boin, 1975; Boin et al., 1968; Bueno et al., 1995; Caielli et al., 1979; Coutinho Filho et al., 1995; Ferrari Jr et al., 1987; Ferreira et al., 1995; Fischer Júnior et al., 1998; Gomes et al., 1994; Hirsch et al., 1974; Juarez Lagunes, 1998; Laredo & Peralta, 1988; Laredo & Peralta, 1990; Leme, 1986; Malafaia et al., 1998a; Marcos et al., 1984; Maroto, 1955; Melotti, 1969a; Melotti, 1969b; Melotti, 1983a; Melotti, 1983b; Melotti, 1986a; Melotti, 1986b; Melotti & Boin, 1969; Melotti et al., 1969a; Melotti et al., 1969b; Melotti et al., 1969c; Melotti et al., 1968; Melotti & Caielli, 1981; Melotti et al., 1970a; Melotti & Lucci, 1969; Melotti & Pedreira, 1970; Melotti & Velloso, 1970; Melotti & Velloso, 1980; Melotti et al., 1970b; Murrieta, 1978; Pereira et al., 1997a; Pereira et al., 1997b; Quadros et al., 1978; Queiroz Filho et al., 1998; Rodrigues & Peixoto, 1993; Rosas et al., 1976; Russi Júnior et al., 1997; Silva & Silva, 1977; Silveira et al., 1979; Velloso et al., 1978a; Velloso et al., 1978b; Velloso et al., 1982; Vieira et al., 1980; Vilela

[1]Home page: http://www.fao.org/WAICENT/FAOINFO/AGRICULT/aga/agap/FRG/TFEED8/index.htm

et al., 1990; Zeoula et al., 1995; Zeoula et al., 1985), and (3) feed analysis and degradation rates data from Mexico, Honduras, Colombia, and Florida (USA) conducted at Cornell University (Juarez Lagunes, 1998; Traxler, 1997).

The data survey of Brazilian research included the following journals: Boletim da Indústria Animal (1960 to 1995), Pesquisa Agropecuária Brasileira (1992 to 1997), Revista Brasileira de Zootecnia (1977 to 1997), and Zootecnia (1970 to 1995), along with several theses and dissertations.

The data collection and organization of this database consisted of three phases: (1) the information reported for each feed was sorted by common name, botanical name, variety, preservation method, fertilization, and region; (2) the coefficient of variation (CV) for each feed component was computed and samples that inflated the CV more than 30% were considered to be outliers and excluded from the database; and (3) feeds lacking crucial information for the CNCPS model (DM, CP, Neutral Detergent Fiber (NDF), and Lignin) were excluded from the database.

In our analysis, tabular TDN refers to the TDN values that were reported in published studies using total collection digestion trials. Studies reporting measured TDN gathered after 1987 were pooled with TDN values collected by Roston & Andrade (1992b). The tabular TDN value for a feed often is not related to the chemical feed composition because analytical information from several sources generally is used. Therefore, the TDN value is the average from several research papers and the feed chemical analysis values are generally from studies and databases independent of those reporting TDN values. Table 1 depicts the feed chemical composition and TDN values for some literature data.

In order to obtain a more robust and complete tropical feed library, our database was first compared with tabular values published for tropical regions (Fonnesbeck et al., 1984; Göhl, 1975; Göhl, 1981) and the NRC (2000) feed library.

Some of the information on TDN and amino acid profiles (%CP) values were obtained from FAO publications (Göhl, 1975; Göhl, 1981). In these publications, the TDN value was estimated from digestion trials with cattle, sheep, or goats. In addition, information on the amino acid profiles of forages from Tedeschi et al. (2001) was used. The International Feed Number (IFN) and some feed composition data were obtained from Fonnesbeck et al. (1984).

After the initial survey, data were organized into the tropical feed library, and the missing values for carbohydrate and protein fractions were obtained from the NRC (2000) feed library using (1) direct comparison of the feeds from the NRC (2000) feed library and the feed with missing values for similar characteristics and (2) the NRC (2000) feed with the lowest deviation of NDF, Lignin (Lig), and CP for the feed with missing values, as shown by Equation 1:

$$\text{Deviation} = \frac{\sqrt{(\text{NDF}_{\text{NRC}} - \text{NDF}_{\text{Feed}})^2}}{\text{NDF}_{\text{NRC}}} + \frac{\sqrt{(\text{Lig}_{\text{NRC}} - \text{Lig}_{\text{Feed}})^2}}{\text{Lig}_{\text{NRC}}} + \frac{\sqrt{(\text{CP}_{\text{NRC}} - \text{CP}_{\text{Feed}})^2}}{\text{CP}_{\text{NRC}}} \qquad \text{Eq. (1)}$$

These two criteria (direct comparison and Equation 1) ensured that the feed with the most similar fiber and protein content within a feed category was selected to provide the missing values. The approach used in Equation 1 can be extended to other feed composition to enhance feed characteristics comparisons.

The CNCPS model divides feed carbohydrate and protein into four and five pools, respectively. Carbohydrate pools are sugars, organic acids and short oligosaccharides (A), starch and pectic substances (B1), digestible fiber (B2), and an indigestible fiber (C). The protein pools include non-protein nitrogen (A), soluble true protein with rapid (B1), intermediate (B2), and slow (B3) degradation rates in the rumen, and bound protein (C) (Sniffen et al., 1992). For forages listed in this feed library, actual degradation rates were used when available. When they were not available, degradation rates were based on the data of Juarez Lagunes et al. (1999). For determining degradation rates of forages not in this feed library, a table with rates classified by NDFIP content was developed from Juarez Lagunes et al. (1999) dataset.

Calculation of the Total Digestible Nutrients

The tabular TDN value of the tropical feed library was compared with the predicted TDN value using the CNCPS version 4.0 model (Fox et al., 2000) level 1 (the equation developed by Weiss et al. (1992) and Weiss (1993)) and level 2 (TDN predicted by the CNCPS model rumen fermentation simulation as described by Russell et al. (1992) and by NRC (2000)). The Weiss equation calculates TDN based on available soluble carbohydrates, proteins, fatty acids, and fiber, and their true digestibility coefficients, which are assumed to be constant except for protein, which is adjusted for ADFIP. The Weiss TDN is then adjusted for endogenous fecal energy.

The Weiss TDN was estimated for animals with dry matter intake at close to the maintenance requirement (Equation 2). The TDN value at 3x intake may be estimated using equations developed by Van Soest & Fox (1992) or Tedeschi (2001, Chap. 2).

$$\text{TDN}_{1x} = 0.98 \times (100 - \text{NDFn} - \text{CP} - \text{Ash} - \text{EE} + \text{IADFIP}) + \text{dCP} \times \text{CP} + 2.25 \times (\text{EE} - 1) + + 0.75 \times \text{NDFn} - \text{Lignin}) \times [1 - (\text{Lignin}/\text{NDFn})^{2/3}] - 7 \qquad \text{Eq. (2)}$$

For forage: Indigestible ADFIP(IADFIP) = 0.7 x ADFIP
For concentrate: Indigestible ADFIP(IADFIP) = 0.4 x ADFIP Eq. (3)

For forage: Digestibility of CP (dCP) = $e^{(-0.012\text{xADFIP})}$
For concentrate: Digestibility of CP (dCP) = 1- (0.004xADFIP) Eq. (4)

NDF adjusted for nitrogen (NDFn) = NDF - NDFIP + IADFIP Eq. (5)

where ADFIP is ADF insoluble protein, CP is crude protein, NDF is neutral detergent fiber, and NDFIP is NDF insoluble protein. All values are expressed as % of the DM.

A simple ration was formulated with the CNCPS model to predict the TDN at 1x for each feed in the library using data from a dual-purpose lactating cow producing 8 kg of milk/d, weighing 600 kg, and 150 days in milk. The standard diet was composed of pangola grass (*Digitaria decumbens*), corn grain, and 49% CP soybean meal, and it was formulated to maintain pH, ruminal N balance and ruminal peptide balance within an ideal range to avoid adjustments to fiber digestibility and microbial yield due to inadequate NDF in the diet. Dry matter intake (DMI) was fixed at 1x using 70% of relative DMI (RDMI). Then, a small amount (100 g) of each feed from the dataset was individually included in this standard diet to obtain predicted TDN and undegraded intake protein (UIP) values. This substitution process was repeated for each feed.

Statistical Analysis

All the statistical analysis was performed using SAS (SAS Institute, 1991). The PROC REG procedure was used to obtain the parameter estimates of the regressions. The plot of studentized residue versus predicted Y-variate and Cook's D influence statistic (SAS Institute, 1991) were used to analyze outliers (Neter et al., 1996), but they are not shown. If the studentized residue was outside of the range –2.5 to 2.5, then it was considered an outlier and removed from the analysis.

Bias was calculated as the slope of linear regression minus one (the regression was forced through the origin) when the intercept of the linear regression did not differ from zero ($P < 0.05$). Otherwise, bias was calculated by dividing the mean of the Y-variate minus the mean of the X-variate by the mean of the X-variate. A positive bias means that the Y-variate has greater values than the X-variate. The reported r^2 and the mean square error (MSE) were obtained from the linear regression not forced through the origin.

RESULTS AND DISCUSSION

Only few digestion trials reported the necessary feed chemical composition values in order to predict TDN using the Weiss et al. (1992) equations as shown in Table 1. The comparison of observed and predicted TDN indicated a mean underprediction of 5.9%. A thorough comparison between observed and predicted TDN was not possible because of insufficient data to characterize the feeds as required by our models.

Table 2 shows the chemical composition of feeds developed for the tropical feed library in the CNCPS format. Table 3 includes the carbohydrate and protein degradation rates, tabular TDN, TDN predicted by the Weiss et al. (1992) equation and by the CNCPS rumen simulation model at 1x and 2x intake at maintenance requirement, and UIP at 1x and 2x predicted by the CNCPS rumen simulation model. Table 4 contains the amino acid composition.

The default intestinal digestibility coefficients are 100, 75, and 20% for carbohydrate fractions A, B1, and B2, and 100, 100, and 80% for protein fractions B1, B2, and B3. Intestinal digestibility of starch (CHO B1) depends on type of grain, degree of processing, and level of intake above maintenance (Fox et al., 2000). Values used in the CNCPS range from 30 to 97% based on experimentally measured digestibility coefficients summarized in the literature (Knowlton et al., 1998; Sniffen et al., 1992).

Table 5 shows the degradation rates for carbohydrate fractions A/B1 and B2, and for protein fraction B3 categorized by NDFIP content of the forage grasses analyzed by Juarez Lagunes (1998). Carbohydrate fraction A/B1 had a better correlation with NDFIP (-0.74) than with ADFIP (-0.58) whereas fraction B2 had a similar correlation between NDFIP (-0.61) and ADFIP (-0.62). These correlations suggest the bound protein in the fiber affects degradation rate in a nonlinear fashion (Van Soest et al., 2000) likely because of limited availability of this protein for fiber digesting bacteria. The degradation rate of the protein fraction B3 had the lowest correlation either with NDFIP (0.54) or with lignin (-0.59).

When we used the mean chemical composition values from the literature data, the TDN predicted by our models did not agree with the measured values. Across all feeds in the library, the regression analysis of tabular TDN values with either the TDN predicted by the CNCPS rumen simulation model (Figure 1A) or that predicted by the Weiss et al. (1992) equations (Figure 1B) had a low r^2 (58.1% and 67.5%, respectively) and high MSE values (67 and 52, respectively), suggesting that the tabular TDN values are not well related to the TDN predicted either by CNCPS rumen simulation or Weiss et al. (1992) equations. This high variation, as discussed by Tedeschi (2001, Chap. 2), may be because (1) feeds used in the digestion trials represented by the TDN values were different than those represented by the chemical composition values of the tropical feed library and (2) errors in the difference method used to predict tabular TDN values. Furthermore, with many of the digestion trials, the TDN value may be confounded with dietary ingredients other than the feed evaluated.

Figure 1C shows the regression between TDN predicted at 1x DMI at maintenance requirement by the CNCPS rumen simulation model and by the Weiss et al. (1992) equations. In contrast to the regressions with tabular TDN, the CNCPS rumen simulation vs Weiss regression had a higher r^2 (92.7%) and lower MSE (13). On average, the Weiss TDN prediction was 0.8 units greater than the CNCPS rumen simulation prediction (60.9% vs 60.1%, respectively), which resulted in a greater prediction of 1.3% of TDN by the Weiss equations. In the evaluation of the NRC (2000) feed library (temperate feeds), Weiss equations were only 1.3 units lower and the r^2 was slightly greater (96%) than the rumen simulation prediction (Tedeschi, 2001, Chap. 2).

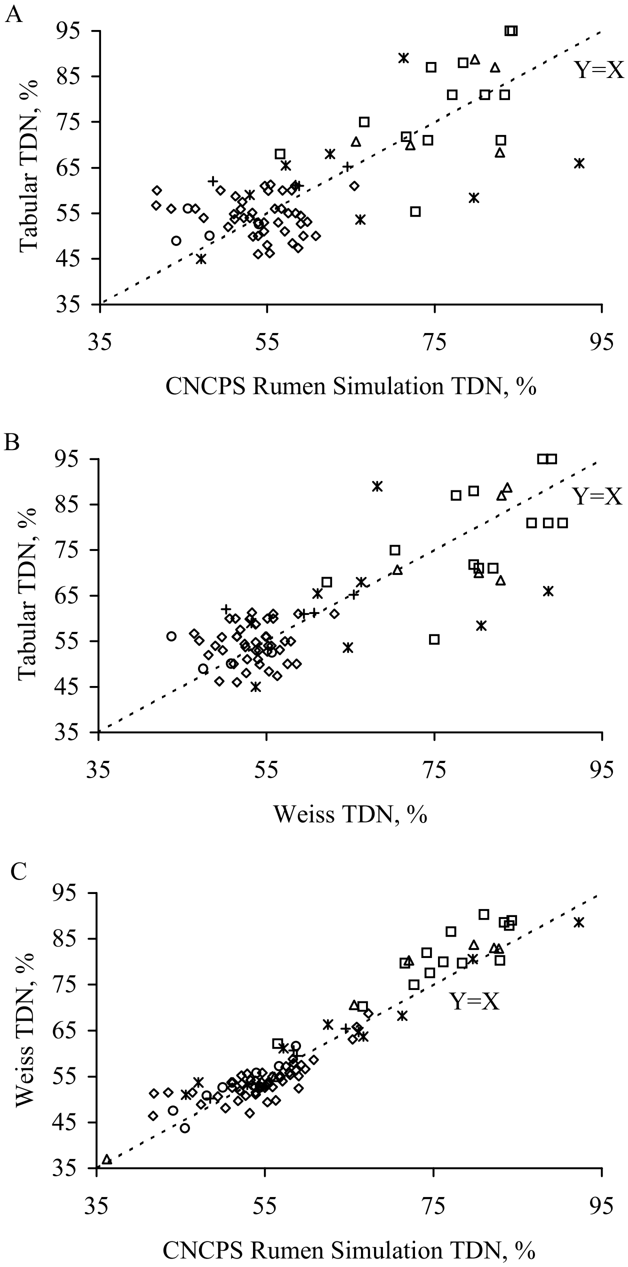

Figure 1 - Evaluation of tabular TDN and TDN predicted at 1x maintenance requirement. Symbols are grass forages (◊), legume forages (o), grain-type forages (+), energy concentrates(◊), protein concentrates (∆), and by–product feeds (*). A positive bias means that Y values are greater than X values. (A) Relationship between tabular TDN and TDN predicted by the CNCPS 4.0 rumen fermentation simulation model. The equation is Y = 16.3 + 0.74X with an r^2 of 58.1%, mean standard error (MSE) of 66.9, and bias of 0.5% ($P > 0.05$). Slope was different from one ($P < 0.05$). (B) Relationship between tabular TDN and TDN predicted by the Weiss et al. (1992) equations. The equation is Y = 15.7 + 0.74X with an r^2 of 67.5%, MSE of 52, and bias of –0.43% ($P > 0.05$). Slope was different from one ($P < 0.05$). (C) Relationship between predicted TDN by Weiss et al. (1992) equations and by the CNCPS 4.0 rumen fermentation simulation model. The equation is Y = -1.57 + 1.04X with an r^2 of 92.7%, MSE of 13, and bias of 0.8% ($P > 0.05$). The slope was not different from one ($P > 0.05$).

Juarez Lagunes et al. (1999) suggested that the rates currently in the CNCPS (Fox et al., 2000) and NRC (2000) feed libraries for carbohydrate A are too high, and further work is needed to determine more accurate values for other feeds for this fraction. The degradation rates of protein fractions still need to be further evaluated.

As DMI increases, forage digestibility decreases due to increased loss from the rumen of potentially digestible NDF. This fraction is the slowest to degrade and therefore is the most likely to escape from rumen degradation (Van Soest, 1994, p. 414). The CNCPS model calculates the passage rate based on body weight, dietary concentration of forage and effective NDF, and DMI (Fox et al., 2000). Tedeschi (2001, Chap. 2) derived equations to discount TDN values for growing/finishing steers and lactating cows based on weight, feed composition, and intake above maintenance requirement. Even though there is a discount in TDN value due to passage rate, it is likely that the efficiency of DE to ME also changes because less methane is produced and the volatile fatty acids (VFA) profile changes. Additionally, a discount for protein is necessary as demonstrated by Van Soest (1994, p. 417). However, despite differences in feed composition between tropical and temperate feeds, which are primarily evident in the fiber fraction (Van Soest, 1994), the digestible energy (DE) of tropical and temperate forages is similar. Roston & Andrade (1992a) found that the energy of TDN of tropical feeds was very similar to that found by Swift (1957) (4.422 and 4.409 Mcal DE/kg TDN, respectively). The NRC (2000) uses 4.409 Mcal/kg to convert DE to TDN. Roston & Andrade (1992a) also reported values of 4.633 for roughages, 4.4 for silages, and 4.014 Mcal/kg for mixed diets.

Comparing the growth of seventeen varieties of alfalfa (*M. sativa* L.) during summer and winter in a humid subtropical climate, Monteiro et al. (1998) found that, on average, CP concentration was lower (19.4 vs 21.5% DM) and that NDF and ADF were greater (48.3 vs 40.8 and 35.2 vs 29.6% DM, respectively) during the summer than in the winter growth period. The authors also observed an interaction of NDF and ADF between varieties and seasons (summer and winter). This information suggests that the classification of tropical forages by age or by season of growth (spring vs summer, rainy vs dry season) is important to ensure adequate forage characterization and the standardization of feed identification.

Several tropical feeds have been evaluated for chemical composition and ruminal degradation by Malafaia et al. (1998b). However the use of different curves to estimate the degradation rate of NDF is not recommended because they result in different estimates of digestion rate. The degradation rates (b) have been estimated in the CNCPS feed library using the exponential equation with lag (c) (Eq. 6) as discussed by Schofield & Pell (1995a; 1995b) and Schofield et al. (1994).

Table 1 - Measured chemical composition and total digestible nutrients (TDN) of feeds from digestiorials.

Name	Preservation	Ref[1]	CP[2]	EE[2]	CF[2]	Ash	TDN[2]	
			%DM	%DM	%DM	%DM	Obs.	Pred.
Black oats (*Avena strigosa*)	Hay	6	11.8	2.5	36.2	11	53.5	51.1
Palisadegrass (*Brachiaria brizantha*)	Hay	4	3	0.8	38.8	6.4	47.9	---
Palisadegrass (*Brachiaria brizantha*)	Hay	15	7.4	2.3	35.3	10.5	54.2	---
Signalgrass (*Brachiaria decumbens*)	Hay	15	7.2	2.3	36.9	9.5	55.1	---
Paragrass (*Brachiaria mutica*)	Fresh	25	11.3	3.3	29	8.7	57.1	---
Brewers	Dry residue	4	34.8	5.9	16.3	5.7	70.7	---
Cassava (*Manihot utilissima*)	Hay	8	22.7	7.1	26.1	9.6	42.3	---
Corn (*Zea mays*)	Rolão	31	7.5	2.7	30.4	4.3	45.9	---
Corn (*Zea mays*)	Rolão	36	6.1	1.9	17.3	4.5	64.8	---
Corn (*Zea mays*)	Silage	10	7.8	4.5	32.8	6.1	63.5	---
Corn (*Zea mays*)	Silage	22	7.7	5.2	24.1	4.1	70.9	---
Corn (*Zea mays*)	Silage	23	6.5	4.9	28	4.9	63	---
Corn (*Zea mays*)	Silage	24	6.9	4	31.2	4.9	65.4	---
Corn (*Zea mays*)	Silage	31	7.6	5	30.5	4.7	57.4	---
Corn (*Zea mays*)	Silage	36	7.8	2.7	20.2	5.3	64.4	---
Corn (*Zea mays*)	Silage	37	7.9	1.3	21	5.2	70.3	---
Cottonseed (*Gossypium* spp.)	Whole	3	22.1	18.9	23.9	3.8	71.8	78.5
Bermudagrass (*Cynodon dactylon*)	Hay	18	10.5	1.9	36.4	6.1	51	49.5
Napiergrass (*Pennisetum purpureum*)	Fresh	11	2.9	2.1	40.4	7.4	51.2	---
Napiergrass (*Pennisetum purpureum*)	Fresh	25	13.5	3.4	31.7	9.1	64.2	---
Napiergrass (*Pennisetum purpureum*)	Fresh	34	7.4	3.3	35.1	13.4	56.5	---
Napiergrass (*Pennisetum purpureum*)	Hay	1	8.9	1.7	---	13	61.3	48.9
Napiergrass (*Pennisetum purpureum*)	Silage	17	7.2	5.5	36.9	9.9	56	---
Napiergrass (*Pennisetum purpureum*)	Silage	23	7.6	3.8	38.5	9.5	55.7	---
Napiergrass (*Pennisetum purpureum*)	Silage	24	6.5	4	33.5	10.7	54.6	---
Napiergrass (*Pennisetum purpureum*)	Silage	35	6.6	3.7	39.7	8.9	60.4	---
Jaraguagrass (*Hyparrhenia rufa*)	Fresh	12	2.7	1.7	43.2	7.6	45.2	---
Jaraguagrass (*Hyparrhenia rufa*)	Fresh	21	5.2	2.6	36.8	8	47.9	---
Molassesgrass (*Melinis minutiflora*)	Fresh	26	6.1	2.9	33	7.2	54.4	---
Molassesgrass (*Melinis minutiflora*)	Hay	19	3.2	2.6	40.8	5.8	41.4	46.2
Molassesgrass (*Melinis minutiflora*)	Hay	28	5	3.4	36.5	6.5	53.4	---
Pangolagrass (*Digitaria decumbens*)	Hay	9	6.4	1.9	40.4	7.3	62.3	---
Pangolagrass (*Digitaria decumbens*)	Hay	32	5.6	2.7	32.5	5.4	54.8	---
Pangolagrass (*Digitaria decumbens*)	Hay	38	8.1	2.7	27.2	7.8	62.7	---
Guineagrass (*Panicum maximum*)	Fresh	20	6.1	2.3	35.6	8.5	48.7	---
Guineagrass (*Panicum maximum*)	Hay	16	7.7	1.7	38	11.8	47.4	---
Guineagrass (*Panicum maximum*)	Hay	40	8.3	2.9	39.1	6.3	53.2	48.2
Guineagrass (*Panicum maximum*)	Silage	40	8.4	4.5	42.1	7.6	49.9	51.7
Pearlmillet (*Pennisetum americanum*)	Silage	13	7.2	2.2	35.3	9.1	48.5	---
Perennial Soy (*Neonotonia wightii*)	Fresh	27	15.7	5.5	34.7	7.5	57.5	---
Perennial Soy (*Neonotonia wightii*)	Hay	27	13.3	3.9	42.3	7.2	55.3	---
Perennial Soy (*Neonotonia wightii*)	Hay	28	16.8	3.6	36.7	9.6	55.4	---
Perennial Soy (*Neonotonia wightii*)	Hay	33	13.4	2.1	39.7	9.4	53.6	---
Sorghum (*Sorghum vulgare*)	Silage	2	6.6	3.5	---	5.3	67.4	56.4
Sorghum (*Sorghum vulgare*)	Silage	5	7.5	5.8	36.5	5.9	68.2	58.7
Sorghum (*Sorghum vulgare*)	Silage	14	8.1	5.5	36.3	5.8	57.3	58.3
Sorghum (*Sorghum vulgare*)	Silage	23	5.1	4.6	27.5	5.1	60.2	58.1
Sorghum (*Sorghum vulgare*)	Silage	24	5.6	5.1	31.4	4.7	62	59.1
Sorghum (*Sorghum vulgare*)	Silage	28	5.7	4.5	39.8	4.3	61.9	58.7
Sorghum (*Sorghum vulgare*)	Silage	29	6.4	6	40.6	5.4	63	59.5
Sorghum (*Sorghum vulgare*)	Silage	30	6.2	3	41.4	6.8	54.1	54.3

Soybean (*Glycine max*)	Meal	22	43.6	12.7	4.1	6.8	68.4	-–
Soybean (*Glycine max*)	Milk	22	42	22.1	6.2	4.3	67.5	-–
Sugarcane (*Saccharum officinarum*)	Fresh	7	2.7	3.5	26.7	3.7	65.5	-–
Sugarcane (*Saccharum officinarum*)	Fresh	22	2.4	1.4	25.7	2.3	65.4	-–
Sugarcane (*Saccharum officinarum*)	Bagasse	3	1.8	2.3	39.8	3	59	46.3
Yeast (*Saccharomyces cerevisae*)	Dry	39	33.5	2.5	0.5	5.3	88.8	-–

[1] References: (1) - Gomes et al., 1994; (2) - Alvarenga, 1993; (3) - Zeoula et al., 1995; (4) - Zeoula et al., 1985; (5) - Melotti, 1986a; (6) - Andrade et al., 1987; (7) - Melotti, 1986b; (8) - Araújo & Languidey, 1982; (9) - Ferrari Jr et al., 1987; (10) - Melotti, 1983a; (11) - Melotti, 1983b; (12) - Velloso et al., 1982; (13) - Andrade & Andrade, 1982; (14) - Melotti & Caielli, 1981; (15) - Andrade et al., 1994; (16) - Barbosa et al., 1985; (17) - Melotti & Velloso, 1980; (18) - Bueno et al., 1995; (19) - Caielli et al., 1979; (20) - Velloso et al., 1978a; (21) - Velloso et al., 1978b; (22) - Andrade et al., 1990; (23) - Boin et al., 1968; (24) - Melotti et al., 1968; (25) - Melotti & Lucci, 1969; (26) - Melotti, 1969b; (27) - Melotti et al., 1969b; (28) - Melotti et al., 1969c; (29) - Melotti & Boin, 1969; (30) - Melotti et al., 1969a; (31) - Melotti, 1969a; (32) - Melotti et al., 1970b; (33) - Melotti & Velloso, 1970; (34) - Melotti & Pedreira, 1970; (35) - Melotti et al., 1970a; (36) - Silveira et al., 1979; (37) - Vieira et al., 1980; (38) - Becker et al., 1962; (39) - Leme, 1986; and (40) - Murrieta, 1978.
[2] CP =Crude protein, EE = Ether extract, CF = Crude fiber, TDN = Total digestible nutrients, Obs. = TDN observed from digestion trials, and Pred. = TDN predicted by Weiss et al. (1992) equation.

Table 2 - Chemical composition of typical tropical feeds[1].

Feed	Name	Fert[2]	Origin	IFN[2]	Conc[2]	Forage	DM	NDF	Lignin	CP	SolCP	NPN	NDFIP	ADFIP	CHO:B1	EE	Ash	eNDF
					%DM	%DM	%AF	%DM	%NDF	%DM	%CP	%SolCP	%CP	%CP	%NSC	%DM	%DM	%NDF
	Alemangrass (*Echinochloa polistachya*)																	
1	Fresh (2)	Y	Mexico		0	100	15.2	68.3	4.7	9.3	29.6	74.8	25.6	4.8	38.5	1.8	12.3	41
								6.4	0.6	1.4	1.2	12.7	1	2.1	5.4	0.5	1	
	Alfalfa (*Medicago sativa*)																	
2	Hay (7)		Brazil	1-00-078	0	100	89.5	66.9	18.1	19	30	93	1	0.5	10	1.9	10.4	92
							2			7.3						0.2	3.4	
3	Silage (1)		Brazil	3-00-212	0	100	49.7	43.5	18.3	18.6	45	100	19.8	10.4	10	1.7	9.6	81
	Bahiagrass (*Paspalum notatum*)																	
4	Fresh (2)	Y	Mexico	2-00-464	0	100	19.1	71	6	10.5	19.7	58.4	43.2	8.3	46.4	1.4	10.7	41
								0.5	0.6	0.1	6.5	26.4	4.1	0.4	0.2		0.7	
	Bermudagrass (*Cynodon dactylon*)																	
5	Fresh (7)		Brazil	2-00-712	0	100	24.7	79.8	8.4	9.4	25.9	25.4	4.5	1.7	6	1.4	7.2	98
							5.5			3.7						0.4	1.3	
6	Hay		Brazil	1-00-703	0	100	88.2	75.5	7.5	10.6	28.9	96	35.9	5.4	6	1.5	6.8	98
							3	5.8	1	3.7	6.5		18.4	3.2		0.6	2.2	
							55	13	9	55	3		5	6		50	55	
7	Hay (7)		Florida	1-00-703	0	100	89.4	81	9.6	9.8	15.6	96	47.3	23.1	6	1.5	7	98
							0.2	5.7	1.3	2.9	5.7		20.5	6.5			3.1	
	Black oats (*Avena strigosa*)																	
8	Hay		Brazil	1-03-280	0	100	88.6	75.8	7.5	13.7	30	93	30	10	90	3.6	6.4	98
							3.1	7.3		4.5						1.4	2.7	
							8	2	1	8						7	8	
	Blood																	
9	Meal (1)		Brazil	5-00-380	100	0	84.1	0	0	89.8	5	0	1	1	0	0.4	4	0
	Brewers																	
10	Dry residue (5)		Brazil	5-02-141	100	0	90.2	52.3	5.2	17.6	4	75	40	3.5	100	3.3	5.4	18
							1			9.7						2.3	1	
11	Wet residue		Brazil	5-02-142	100	0	15.2	58	6.8	30.1	8	50	62.8	11.7	100	10.1	3.9	18
							3.5	13.3	4.3	2.8						1.4	0.7	
							35	2	2	35			1	1		35	35	
	Buffelgrass (*Cenchrus ciliaris*)																	
12	Hay		Brazil		0	100	92	75.7	11.2	3.7	24.3	5	40.5	21.6	0	3	4.7	41
	Calopo (*Calopogonium mucunoides*)																	
13	Hay (2)		Brazil		0	100	91.6	52.5	23	13	29.3	28	26	8.7	10	1.2	6	92
							1.4			2.9							1.3	
	Cassava (*Manihot utilissima*)																	
14	Residue (3)		Brazil		100	0	18.8	20.2	12	2.2	25	45	30	5	13.6	0.2	1.4	0
							3	3.4	1.8	0.5							0.3	
	Citrus																	
15	Pulp		Brazil	4-01-235	100	0	86.9	18.2	10	7.1	27	96	21.1	16.34	90	2	6.1	33
							5.9	4.7	3.8	0.6						0.7	1.5	
							8	4	3	8			1	1		8	8	
	Congograss (*Brachiaria ruziziensis*)																	

Feed	Name	Fert²	Origin	IFN²	Conc² %DM	Forage %DM	DM %AF	NDF %DM	Lignin %NDF	CP %DM	SolCP %CP	NPN %SolCP	NDFIP %CP	ADFIP %CP	CHO:B1 %NSC	EE %DM	Ash %DM	eNDF %NDF
16	Hay		Brazil		0	100	91.2	75.5	10.6	3.4	38.2	2.4	38.2	17.6	6	2.1	6.3	41
	Corn (*Zea mays*)																	
17	Cracked (9)		Brazil	4-02-698	100	0	87.9	10.9	7.3	9.2	17.8	30	6.8	2.3	90	4	1.9	60
							1.1		7.3	1.2			8.5	3.1		1.3	1.4	
18*	Grain		Brazil	4-02-935	100	0	88	13.4	2.8	9.5	11	73	10.7	4	90	4.4	1.5	88
							1	3.3		1.2						1.3	0.3	
							17	3	1	16			1	1		15	17	
19#	Rolão MPS (1)		Brazil		80	20	87.5	21.36	3.86	30.4	17.08	78.06	11.48	5.36	92	2	4.8	86.6
20	Rolão Total (2)		Brazil		70	30	89.4	33.3	5.45	6.8	26.2	85.65	12.65	7.4	95	2.3	4.4	84.5
							1.1			1						0.6	0.2	
21	Silage		Brazil	3-02-912	20	80	31.4	53.2	8.1	7.1	41.4	98.3	14.6	10.8	100	2.5	4.2	81
							7	7.2	3.9	1.3		0.7	8.1	4.6		0.7	1.2	
							165	28	8	165	2	2	5	24		155	162	
22	Silage (2)		Honduras	3-02-912	20	80	87.2	56.3	10.3	8.3	47	100	19.3	9.6	100	2.1	6.5	81
	Cottonseed (*Gossypium* spp.)																	
23	Meal		Brazil	5-17-728	100	0	90.1	46.9	15.1	37.9	20	40	9.3	1.5	90	1.5	5.8	36
							1.3	12		6.6						0.7	0.8	
							19	3	1	19			1	1		17	18	
24	Whole		Brazil	5-01-614	100	0	89.5	44.1	23	22.6	12.3	57.7	12	7.5	6	16.6	4.1	36
							2.3	10.1	7.1	7.6	4.4		6.8	2		4.8	0.8	
							15	5	4	15	2	1	3	5		15	15	
	Enterolobium (*Enterolobium cyclocarpum*)																	
25	Hay		Honduras		0	100	87.3	28.9	24.2	20.2	28	96	12.9	11.9	10	2.1	4.2	92
	Gambagrass (*Andropogon gayanus*)																	
26	Fresh (3)	N	Mexico	2-00-825	0	100	27.8	71.9	5.6	6.2	21.9	80	49.9	7.1	35.6	1.6	7.4	41
								0.2	0.6	0.4	7	21.8	6.4	1.4	2.6	0.2	0.5	
27	Fresh (2)	Y	Mexico	2-00-825	0	100	20.8	67.7	6.7	12.1	18.2	85.9	46.7	6.1	42.6	2.6	8.9	41
								0.2	0.1	0.8	6	19.9	9.6	0.8	3.6	0.5	1	
28	Hay (3)		Honduras		0	100	89	72.1	6.4	11.4	18.5	80	54.2	9.4	35.6	1.7	12.8	98
							0.2	1.8		0.7	2.8		7	3.8			1.3	
	Gliricidia (*Gliricidia sepium*)																	
29	Hay		Honduras		0	100	88.5	37.3	24.4	24.4	31.6	96	25.4	11.9	10	3.2	8.6	92
	Guineagrass (*Panicum maximum*)																	
30	Fresh (12)	N	Mexico	2-09-409	0	100	26.1	72.6	6.4	6.1	33.2	83.7	35.3	8.6	31.3	2	9.8	41
							1.7	2.1	1.1	1.4	5.1	9.2	2.1	2.2	10	0.2	0.8	
31	Fresh (2)	Y	Mexico	2-09-409	0	100	18.4	66.9	6.8	9.6	28.7	39.2	34.5	8.1	38.1	3	12.7	41
								0.6		1.1	1.3	2.3	3.8	1.2	10.7	0.1	0.2	
32	Hay (24)		Brazil		0	100	89.5	75.7	8.6	8.4	29.1	96	37	9.9	6	1.7	7.7	98
							1.6	5.4	1.2	2.8				1.1		0.6	2.0	
33	Hay (2)		Honduras		0	100	88.8	66.6	6.8	14.9	35.5	96	39.7	4.4	6	1.5	13.4	98
							0.8	2.5	0.5	1.3	2.7		1.5	0.1			0.7	
34	Pasture (2)		Honduras		0	100	91.3	66.7	6.1	10.3	32.4	3.41	43.7	9.2	8	3.2	12.4	41
							2.1	2.5	0.7	0.9	4.3		4.4	1.2			0.5	
35	Silage (4)		Brazil		0	100	24.7	73.7	8.3	8.0	54.7	25.0	33.3	13.7	100	4.0	8.9	41
							1.4	1.6	0.3	0.8	0.6	2.6		0.5		1.1	2.6	
36	Silage		Honduras		0	100	87.5	60.7	9.6	10.5	39	90	33.3	14.3	100	2.8	17.1	41
	Jaraguagrass (*Hyparrhenia rufa*)																	
37	Hay (4)		Brazil		0	100	91	72.8	6.6	7.8	18.6	5	51.9	7.9	0	3	9.7	98
							0.6	4.6	1.6	4	2.9		11	2.7			2.4	
	Koroniviagrass, Creeping signalgrass (*Brachiaria humidicola*)																	
38	Fresh (3)	N	Mexico		0	100	22.9	75.7	8.1	6	47	50.5	21.2	7.3	21.2	1.6	6.6	41
							2.1	1.4	1	1.3	2.2	4	2.9	1.9	6.7	0.3	0.6	
39	Fresh (2)	Y	Mexico		0	100	14	70.3	7.2	9.8	39.9	53.6	17.1	4.3	35.1	2	10.6	41
								1.2	0.7	1	4.2	0.8	0.3	0.6		0.1	0.7	
40	Hay		Brazil		0	100	93.6	79	7.5	4.4	25	5	36.2	16	0	0.9	5.3	98
							2.9			1.4						0.2	1.1	
							3	1	1	3			1	1		2	3	
	Kudzu, Puero (*Pueraria phaseoloides*)																	
41	Hay		Brazil		0	100	92.4	53.9	21.5	14	26	5	32.9	18	0	1.6	8	92
	Leucaena, Leadtree, Kao haole (*Leucaena leucocephala*)																	
42	Hay		Brazil	1-02-492	0	100	94.7	64.3	21.4	11.7	25	5	33.9	14.5	38	0.7	4.8	98
	Llanerograss (*Brachiaria dictyoneura*)																	

Feed	Name	Fert[2]	Origin	IFN[2]	Conc[2] %DM	Forage %DM	DM %AF	NDF %DM	Lignin %NDF	CP %DM	SolCP %CP	NPN %SolCP	NDFIP %CP	ADFIP %CP	CHO:B1 %NSC	EE %DM	Ash %DM	eNDF %NDF
43	Fresh (3)	N	Mexico		0	100	22.4	74	5.4	5.4	41	59.9	22.7	8.2	26	1.3	8.4	41
							3.5	3.1	0.8	2.4	2.8	8	4.1	4.6	2.2	0.3	0.9	
44	Fresh (2)	Y	Mexico		0	100	18.4	69.9	6.1	7.7	41.5	56.1	20.8	5.8	32.1	1.8	10.9	41
								2	0.1	1.3	3.2	1.7	3	0.8	11.7	0.2	0.3	
	Meat																	
45	Meal (6)		Brazil	5-07-314	100	0	94.7	0	0	46.9	8.6	26.5	0	0	0	12	37.5	0
							1.7			4.8						2.4	5.5	
	Meat and Bone																	
46	Meal		Brazil	5-00-388	100	0	95.1	0	0	46.1	16.09	21.4	0	0	0	11	40.8	0
	Molasses																	
47	Sugarcane		Mexico		100	0	85.8	0	0	4.2	98	100	0	0	0	2.2	11.6	0
	Molassesgrass (*Melinis minutiflora*)																	
48	Fresh (2)		Brazil		0	100	30.1	78.3	6.8	7.1	25	5	3.4	1.7	0	2.2	8.3	98
							3.4			1.5						1	1.5	
49	Fresh (2)	Y	Mexico		0	100	17.6	70.2	4.7	8.6	27.9	50.1	33	4.9	0	2.5	12.8	41
								0.2	0.2	0.3	4.6	3.5	0.2	0.2			0.3	
50	Hay (5)		Brazil		0	100	90.8	81.5	10.3	3.9	25	5	2	1	0	2.9	6.1	98
							0.7	0.9	3.1	1.2						0.5	0.5	
	Napiergrass (*Pennisetum purpureum*)																	
51	Fresh (10)		Brazil	2-03-162	0	100	23.7	74	9.6	6.6	46	2.2	2.2	0.9	8	2.3	9.4	41
							6.9	3.1	1.5	2.9						1	2.5	
52	Hay		Brazil	1-08-462	0	100	91.3	65.8	7.3	10.4	32.4	95	39.7	10	10	1.7	11.8	98
							1.8	10.5	2.6	3.4	14.7		6.5	6			3.1	
							6	6	5	7	5		5	6		1	7	
53	Silage		Brazil		0	100	23.8	78.4	12.2	5.4	50	90	52.6	26.1	100	2.3	7.7	41
							8.2	2.4	3.1	1.6				9.2		1.2	2.1	
							18	3	2	18			1	2		17	18	
	Palisadegrass (*Brachiaria brizantha*)																	
54	Fresh		Brazil		0	100	25.1	76.4	8.3	7.1	41	2.4	4.6	2.1	5	1.6	7.6	41
							4.6	5.7		2.6						0.6	1.6	
							11	2	1	11			1	1		11	11	
55	Fresh (3)	N	Mexico		0	100	25.1	67.8	5.3	7.1	45.9	70.7	15.9	3.8	32.7	2	8	41
								2.3	0.4	1.6	2	6.3	1.3	0.5	2.1	0.2	0.3	
56	Fresh (2)	Y	Mexico		0	100	19.8	63.7	5.9	11.7	37.5	68.3	10.1	2.9	26.5	2.8	11.1	41
								3.1	0.1	0.7	1	5.2	3.5	0.5	10.7	0.4	0.3	
57	Hay (19)		Brazil		0	100	88.8	75.2	5.9	5.9	38.2	5	33.7	10.5	0	1.4	7.2	98
							4.3	1.2	1.7	3.1			10.5	2.2		0.6	2.1	
	Pangolagrass (*Digitaria decumbens*)																	
58	Fresh		Mexico	2-01-668	0	100	26.8	69.5	7.5	8.9	41.9	36.3	32.5	5.4	28.2	2.4	8.6	41
59	Fresh (3)	N	Mexico	2-01-668	0	100	26.8	70	7.3	7	36.7	38.3	31.3	6.1	31.5	1.8	8	41
								0.7	0.3	2.3	4.6	2	1.9	0.7	3.1	0.6	0.7	
60	Hay (5)		Brazil	1-01-667	0	100	88.9	72.3	9.6	7.3	30.9	96	38.2	16.4	6	2.3	6.9	98
61	Hay (2)		Honduras	1-01-667	0	100	89.9	63.9	7.2	14.2	29.6	96	42.9	8.1	6	1.6	13.8	98
							3.3	0.9	0.3	4.7	3.9		9.6	4.2			0.8	
62	Hay (13)		Florida	1-01-667	0	100	89.7	76.8	9	8.7	14.1	96	66.8	22.9	6	1.6	7.5	98
							0.5	4.9	1.3	3.3	4		4.4	6.8			2	
63	Pasture (3)		Honduras		0	100	90.2	65.5	5.5	11.1	42.2	5	34.5	10.8	0	3	10	41
							2.9	3.7	0.5	5.9	7.5		4	2.6			1.3	
	Paspalum (*Paspalum fasciculatum*)																	
64	Fresh (2)	Y	Mexico		0	100	18.5	63.5	5.7	11.9	15.1	87.1	41.9	6.5	55.8	1.2	14.2	41
								0.8	0.2	0.2	0.5	6.1	2.5	0.5	11.4	0.1	1.3	
65	Hay (8)		Florida	1-00-462	0	100	89.4	80.8	7.3	9.9	12.7	25.4	75	29.7	6	1.6	5.5	98
							0.2	2.4	0.9	3.1	3.1		4.2	18.1			0.4	
	Pearlmillet (*Pennisetum americanum*)																	
66	Grain (2)		Brazil	4-03-118	100	0	88	27.3	7.1	15.1	53	19	32.8	18.9	90	3.8	2	34
							0.4			0.1						0.8	0.1	
	Perennial soy (*Neonotonia wightii*)																	
67	Fresh (2)		Brazil		0	100	33.2	57.2	19.9	15.8	28	96	4.6	4.3	10	3.4	8	92
							8			0.1						3.1	0.8	
68	Hay (5)		Brazil		0	100	90.1	51.6	22.9	15.4	33.7	96	24.8	9.9	10	3.2	8	92
							1.9	3.4	1.1	1.9	6.2		0.6	1.9		1	1.5	
	Poultry																	

Feed	Name	Fert[2]	Origin	IFN[2]	Conc[2] %DM	Forage %DM	DM %AF	NDF %DM	Lignin %NDF	CP %DM	SolCP %CP	NPN %SolCP	NDFIP %CP	ADFIP %CP	CHO:B1 %NSC	EE %DM	Ash %DM	eNDF %NDF
69	Bedding (47)		Brazil	5-05-587	65	35	82	39.1	9.4	20.4	46	2.17	12	9.2	8	1.3	18.5	41
							5.1			4.3				2.7		0.6	7.9	
70	Manure		Brazil	5-14-015	65	35	84	16	2.3	15.8	53	19	7	4	90	0.5	49.8	34
	Setaria, Golden Timothy, Kazangula (*Setaria sphacelata*)																	
71	Hay (3)		Brazil		0	100	92.2	66.9	3.8	12.1	18.4	5	45.9	5.1	0	3	8.2	98
							0.4	8.1	0.4	4.8	2		10	0.1			1.7	
	Signalgrass (*Brachiaria decumbens*)																	
72	Fresh		Brazil		0	100	28.9	75.8	7.5	7.2	42	4.8	2.1	0.8	5	1.2	8.2	41
73	Fresh (3)	N	Mexico		0	100	23.2	71.3	6.3	7.1	46.6	68.6	15.8	4.3	24.8	1.8	7.9	41
							3.6	4.8	0.7	2.8	2.9	5.6	0.8	1.8	3.7	0.3	0.5	
74	Fresh (2)	Y	Mexico		0	100	20.1	67.1	6.5	8.9	40.4	64.7	10.6	4.5	21.2	2	10.3	41
								3.3	1	1.8	1.9	13.9	0.7	0.5	2		2	
75	Hay (8)		Brazil		0	100	88.8	84.2	10	5.5	38.5	5	13.3	6.1	0	2.3	7	98
							3.3	13.1	0.6	2.1			16.5	7.7		1.9	2.7	
	Siratro (*Macroptilium atropupureum*)																	
76	Hay		Brazil		0	100	92	47.5	22.7	18.8	28.7	96	16	8	10	3	8.2	92
	Sorghum (*Sorghum vulgare, Sorghum bicolor*)																	
77	Grain cracked		Brazil	4-04-383	100	0	87.2	24.2	9.2	9.9	12	33	1.9	0.1	100	8.7	0.9	34
78	Grain whole (3)		Brazil	4-04-383	100	0	88.2	11.2	2.22	8.9	13	41.9	15	5	90	5.1	2	60
							0.8			1.2						2.7	1	
79	Grain		Mexico	4-04-383	100	0	87.4	10.3	12.8	10.4	14.9	33	33.9	5	90	3.6	3	34
80	Residue (3)		Honduras		0	100	88.2	66.2	10	8.8	51.3	96	20.9	12.8	6	2.3	11.1	98
							0.6	10.7	2.1	4.6	15.6		2.9	1.5			4.4	
81	Silage		Brazil	3-04-323	20	80	28.8	61.6	9.4	6.2	45	100	19.6	16.8	100	3.5	5.3	81
							5.2	11.5	0.1	1.6						1.5	1.3	
							31	6	2	31			1	1		29	29	
82	Silage		Honduras	3-04-323	20	80	89.4	69.6	10.2	3.2	34.4	100	34.4	18.8	100	2.64	10.6	81
	Soybean (*Glycine max*)																	
83	Grain (3)		Brazil	5-04-610	100	0	91.6	19.1	1.54	40.5	44	22.7	4	3	90	23.1	4.9	100
							0.8			1.2						3.4	0.3	
84	Hulls		Brazil		100	0	89.8	62.7	3.2	13.4	18	72	21.1	5.8	90	2	5.5	2
							0.9	4.2	1.1	2.8				0.1		1	0.5	
							5	4	3	5			1	3		5	5	
85	Meal		Brazil	5-04-600	100	0	88.7	14.1	19	47	35.9	11.1	2.8	1.6	90	5.5	6.2	23
							1.4	1.7	12.8	4.5			1.5	0.9		7.1	1.1	
							19	4	3	19	1	1	3	3		16	18	
86	Meal		Mexico	5-04-600	100	0	89	11.4	0.9	52.6	16	55	5.5	2	90	2	7	23
87	Residue		Brazil		100	0	89.4	28.5	9.1	23.4	12.7	2.17	15.1	6.4	8	8.7	8.2	41
							1.8	11.5	3.1	8.6	6.9		13	2.6		4.2	3.1	
							22	3	2	22	2		2	2		22	22	
88	Straw (3)		Brazil	1-04-567	0	100	87.4	56.8	1.9	11.9	70	100	33.3	27	100	2.8	10.5	65
							4.4			1.1						0.7	6.1	
	Stargrass (*Cynodon plectostachyus*)																	
89	Fresh (3)	N	Mexico		0	100	30.2	76.8	7.6	6.7	35.6	31.4	42.7	10.8	28	1.1	7.7	41
							3.8	2.7		0.2	12.5	11.1	1.1	4	2	0.1	0.3	
90	Fresh (2)	Y	Mexico		0	100	21.5	71.6	7.3	10	35.7	40.1	34	8	22.6	1.6	11	41
								2.5	0.2	1.3	2.5	7	3.6	1.6	4.6	0.2		
	Sugarcane (*Saccharum officinarum*)																	
91	Bagasse		Brazil	1-04-686	0	100	15.6	75.6	11.3	2.6	20	95	75	65	100	1.8	1.9	100
92	Fresh (10)		Brazil	2-04-689	0	100	29.7	57.1	11	2.5	55	100	16	9	0	1.4	2.9	81
							3.5			0.5						1.2	1	
93	Bagasse,hidrolized		Brazil		0	100	46.9	61.4	15.8	1.8	42	5	45.8	50.4	0	1.4	4.6	41
							3.4	3.2	2.2	1.3				20.6		2	2.5	
							20	3	2	12			1	3		10	21	
	Wheat (*Triticum* spp.)																	
94	Hay (2)		Brazil	1-05-172	0	100	89	55	3.5	4.1	20	95	75	65	100	0.9	6.1	98
							0.3			3.8						0.2	4.3	
95	Middling		Brazil		100	0	88.3	43	11.2	17.6	53	19	3	0.5	90	5.3	5.6	34
	Yeast (*Saccharomyces cerevisae*)																	
96	Dry (9)		Brazil	7-05-533	100	0	91.7	11	0	31.9	44	22.7	22.3	3.2	90	0.4	6.7	10
							2.1	0.5		4.4			1.2	0.6		0.8	3	

[1]Values are mean, standard deviation, and sample size, respectively. Number in parenthesis after the feed name is the sample size if it was the same across all fractions of the feed.

[2] Fert = Fertilization (Yes/No), IFN = International Feed Number, and Conc = Concentrate. Symbols for all tables are (*) composition was estimated at 80% of feed 18 (corn grain) and 20% of feed 21 (corn silage) and (#) composition was estimated at 50% of feed 18 (corn grain) and 50% of feed 21 (corn silage).

Table 3 - Carbohydrate and protein degradation rates (%/h), total digestible nutrients (%DM), and undegraded intake protein (%CP) of typical tropical feeds.

	Degradation rates (kd, %/h)						Total digestible nutrients[1] (%)				UIP (%CP)	
	Carbohydrate			Protein			Tabular	Weiss	CNCPS			
Feed	A	B1	B2	B1	B2	B3	1x	1x	1x	2x	1x	2x
1	22.1	22.1	7.5	135	11.0	8.7	56	55.0	55.9	51.5	23.7	29.5
2	26.8[a]	26.8[a]	8.3[b]	150	9.0	3.6[c]	56	43.7	45.5	43.0	15.6	20.6
3	26.8[a]	26.8[a]	8.3[b]	150	11.0	3.6[c]	---	57.2	56.7	55.3	24.2	27.8
4	18.4	18.4	5.5	135	11.0	6.1	58.7	53.7	51.2	46.7	32.3	38.6
5	26.8[a]	26.8[a]	8.3[b]	135	11.0	3.6[c]	53	49.8	56.3	52.4	16.9	22.0
6	13.1[a]	13.1[a]	6.2[b]	43	5.1	6.8[c]	51	54.0	57.1	53.0	21.3	26.2
7	13.1[a]	13.1[a]	6.2[b]	43	5.1	6.8[c]	52	48.1	50.3	46.2	37.1	41.6
8	17.7[a]	17.7[a]	6.7[b]	135	11.0	5.0[c]	53.1	56.6	59.8	55.8	25.1	29.7
9	0.0	0.0	0.0	75	3.0	0.1	66	88.6	92.3	92.3	34.0	43.2
10	300	38.0	6.0	150	6.0	0.5	70.7	70.6	65.6	62.1	55.2	61.5
11	300	38.0	6.0	150	8.0	0.5	70	80.3	72.1	69.4	68.0	72.2
12	13.1[a]	13.1[a]	6.2[b]	135	10.0	6.8[c]	53.7	52.5	51.1	47.1	38.4	43.3
13	17.7[a]	17.7[a]	6.7[b]	150	9.0	5.0[c]	---	52.6	50.0	48.6	26.6	31.8
14	300	40.0	8.0	300	12.0	0.4	---	80.0	76.2	75.0	44.9	49.9
15	300	40.0	8.0	300	12.0	0.4	87	77.6	74.6	73.0	38.2	43.3
16	13.1[a]	13.1[a]	6.2[b]	135	11.0	6.8[c]	60	50.6	49.4	45.3	32.4	36.6
17	150	15.0	5.0	50	2.9	0.2	95	87.9	84.0	82.2	32.3	39.7
18	300	35.0	6.0	135	10.0	0.2	95	89.0	84.3	81.9	35.8	43.3
19	242	33.0	6.0	127	8.3	0.2	88	79.7	78.4	76.7	32.0	38.1
20	155	30.0	6.0	115	5.8	0.2	55.4	75.0	72.7	70.0	28.9	34.0
21	10	25.0	6.0	94	1.5	0.2	65.2	65.4	64.6	61.1	25.0	28.5
22;	10	25.0	6.0	300	10.0	0.2	61	59.5	58.8	55.4	26.8	29.5
23	300	25.0	3.0	187	9.9	0.2	68	62.2	56.5	54.4	31.4	38.3
24	300	25.0	3.0	175	8.0	0.3	71.8	79.7	71.6	70.3	35.7	42.9
25	26.8[a]	26.8[a]	8.3[b]	150	9.0	3.6[c]	---	68.7	67.3	66.7	28.5	33.4
26	13.2	13.2	7.1	135	11.0	6.7	55	57.2	57.5	53.0	30.7	37.0
27	14.4	14.4	7.4	135	11.0	9.9	55	57.9	58.4	54.4	27.4	33.7
28	13.1[a]	13.1[a]	6.2[b]	43	5.1	6.8[c]	46	51.5	53.9	49.8	28.2	33.9
29	17.7[a]	17.7[a]	6.7[b]	150	9.0	5.0c	---	61.6	58.7	58.0	28.8	33.5
30	9.8	9.8	7.4	135	11.0	6.6	53	53.7	54.6	50.2	27.2	32.2
31	8.3	8.3	6.8	135	11.0	11.0	53	54.1	53.9	49.8	25.9	31.3
32	13.1[a]	13.1[a]	6.2[b]	135	11.0	6.8[c]	47.4	56.3	58.7	54.9	31.6	37.9
33	13.1[a]	13.1[a]	6.2[b]	135	11.0	6.8[c]	48	52.6	55.0	51.3	20.3	25.0
34	13.1[a]	13.1[a]	6.2[b]	200	14.0	6.8[c]	61	55.8	54.7	50.6	29.5	35.0
35	17.7[a]	17.7[a]	6.7[b]	175	12.0	5.0[c]	50	54.2	53.3	48.9	25.7	28.6
36	17.7[a]	17.7[a]	6.7[b]	175	12.0	5.0[c]	54	48.9	47.4	43.9	30.7	34.8
37	13.1[a]	13.1[a]	6.2[b]	135	3.5	6.8[c]	48.4	55.3	58.0	53.9	27.1	33.0
38	17.8	17.8	7.5	135	11.0	2.6	---	52.7	53.8	49.5	24.7	28.7
39	18.6	18.6	7.9	135	11.0	3.2	---	52.8	54.4	50.2	23.5	28.3
40	13.1[a]	13.1[a]	6.2[b]	135	3.5	6.8[c]	---	52.7	55.9	51.5	29.8	34.3
41	17.7[a]	17.7[a]	6.7[b]	150	9.0	5.0[c]	50	50.8	48.1	46.6	34.1	38.8
42	17.7[a]	17.7[a]	6.7[b]	135	3.5	5.0[c]	48.9	47.5	44.1	42.1	31.0	35.9
43	25.5	25.5	8.2	135	11.0	3.4	---	54.8	56.8	52.3	26.1	30.5
44	22.9	22.9	8.1	135	11.0	3.1	---	53.7	55.4	51.2	24.9	29.5
45	0.0	0.0	0.0	150	5.0	0.1	89	68.2	71.3	71.3	32.2	41.1
46	0.0	0.0	0.0	150	6.0	0.1	---	63.7	66.7	66.7	29.8	38.2
47	17.5	17.5	20.0	350	11.0	0.3	71	80.3	82.9	83.4	0.7	0.9
48	26.8[a]	26.8[a]	8.3[b]	52	1.4	3.6[c]	54.4	52.4	59.0	55.0	17.0	22.2

	Degradation rates (kd, %/h)						Total digestible nutrients[1] (%)				UIP (%CP)	
	Carbohydrate			Protein			Tabular	Weiss	CNCPS			
Feed	A	B1	B2	B1	B2	B3	1x	1x	1x	2x	1x	2x
49	10.6	10.6	8.0	135	11.0	7.3	56	54.9	56.7	52.4	25.7	31.6
50	26.8[a]	26.8[a]	8.3[b]	135	3.5	3.6[c]	46.2	49.4	55.3	51.5	16.0	21.2
51	26.8[a]	26.8[a]	8.3[b]	70	1.7	3.6[c]	55.9	49.7	51.8	47.8	16.6	21.4
52	13.1[a]	13.1[a]	6.2[b]	135	11.0	6.8[c]	61.3	53.3	55.4	51.8	24.9	29.4
53	10.0	20.0	5.0	175	12.0	1.5	56.7	46.4	41.7	37.5	44.7	46.4
54	34.8	34.8	8.6	132	11.0	0.3[c]	50	51.1	53.9	49.7	19.8	24.7
55	34.8	34.8	8.6	135	11.0	6.3	50	58.6	60.8	56.6	19.2	23.6
56	20.0	20.0	8.2	135	11.0	4.9	50	57.5	59.3	55.4	20.8	25.9
57	17.7[a]	17.7[a]	6.7[b]	135	3.5	5.0[c]	52.7	55.1	59.0	54.7	25.1	29.4
58	19.7	19.7	5.3	135	11.0	5.3	54	55.6	52.9	48.6	24.7	29.7
59	22.4	22.4	5.2	135	11.0	3.9	54	55.2	52.2	47.9	28.1	33.3
60	13.1[a]	13.1[a]	6.2[b]	135	11.0	6.8[c]	59.9	53.0	55.1	51.4	29.1	33.1
61	13.1[a]	13.1[a]	6.2[b]	135	11.0	6.8[c]	51	52.7	54.6	51.1	24.6	29.6
62	13.1[a]	13.1[a]	6.2[b]	135	11.0	6.8[c]	–	50.8	52.7	48.9	39.3	44.2
63	17.7[a]	17.7[a]	6.7[b]	135	12.0	5.0[c]	61	58.8	58.3	54.3	29.0	33.6
64	9.8	9.8	6.3	135	11.0	6.4	–	53.5	52.3	48.3	32.2	39.0
65	13.1[a]	13.1[a]	6.2[b]	135	11.0	6.8[c]	–	53.3	55.3	51.1	45.0	49.6
66	17.7[a]	17.7[a]	6.7[b]	300	12.0	5.0[c]	71	82.0	74.2	71.0	32.4	35.9
67	26.8[a]	26.8[a]	8.3[b]	65	11.0	3.6[c]	57.5	51.9	52.0	50.0	19.8	24.8
68	17.7[a]	17.7[a]	6.7[b]	150	9.0	5.0[c]	54.8	53.7	51.0	49.6	25.7	30.2
69	350	45.0	10.0	200	18.0	2.0	-–	54.9	56.1	54.1	25.0	29.4
70	300	40.0	8.0	300	12.0	0.4	-–	37.0	36.2	34.9	21.3	25.6
71	13.1[a]	13.1[a]	6.2[b]	135	8.0	6.8[c]	61	63.1	65.4	61.4	25.2	31.4
72	250	30.0	3.0	78	1.2	0.9	60	51.3	41.8	37.2	17.7	22.7
73	26.8[a]	26.8[a]	8.3[b]	135	11.0	3.6	60	55.8	57.9	53.7	20.8	25.1
74	25.6	25.6	8.1	135	11.0	3.1	60	55.1	56.8	52.7	21.6	26.3
75	26.8[a]	26.8[a]	8.3[b]	96	1.9	3.6[c]	55.1	47.0	53.2	49.3	19.0	23.2
76	26.8[a]	26.8[a]	8.3[b]	150	9.0	3.6[c]	52.5	55.7	54.0	52.7	25.3	30.2
77	250	20.0	8.0	35	13.0	0.1	81	88.6	83.4	80.1	30.5	38.9
78	150	15.0	5.0	150	5.0	0.1	81	90.3	81.0	77.5	39.1	46.1
79	14.3	14.3	6.0	135	6.0	0.1	81	86.6	77.1	74.0	51.2	56.5
80	250	30.0	3.0	135	11.0	0.1	-–	51.0	45.6	41.8	26.6	28.6
81	10.0	20.0	5.0	300	8.0	0.2	61.2	60.7	58.4	54.5	27.6	30.3
82	10.0	20.0	5.0	300	8.0	0.2	62	50.2	48.5	44.4	40.4	42.9
83	300	30.0	5.0	200	10.0	0.2	89	108.9	106.4	104.8	21.1	26.5
84	350	40.0	8.0	150	12.0	0.2	68	66.3	62.5	57.8	42.0	48.1
85	300	45.0	6.0	238	8.4	0.4	68.4	82.9	82.8	82.1	24.9	31.4
86	7.9	7.9	5.7	230	11.0	0.2	87	83.0	82.2	80.9	32.6	40.3
87	350	45.0	10.0	200	20.0	2.0	58.4	80.6	79.7	78.2	36.4	44.0
88	300	50.0	10.0	300	10.0	0.5	53.6	64.7	66.1	62.6	31.7	31.7
89	13.1	13.1	3.4	135	11.0	5.2	56	51.5	43.5	38.9	30.9	35.9
90	13.2	13.2	4.2	135	11.0	5.3	56	51.5	46.4	42.0	27.9	33.0
91	250	30.0	3.0	135	11.0	0.1	45	53.7	47.1	42.8	75.7	76.1
92	275	25.0	4.0	300	10.0	0.2	65.5	61.1	57.2	54.0	22.5	24.8
93	250	30.0	10.0	135	10.0	0.2	59	53.2	52.9	50.3	53.7	54.8
94	250	50.0	8.0	135	11.0	0.1	-–	65.8	65.9	62.5	75.9	76.3
95	300	35.0	5.0	113	4.0	0.8	75	70.3	66.6	63.8	18.1	23.0
96	300	30.0	5.0	200	10.0	0.2	88.8	83.7	79.8	78.8	34.7	38.9

[1]Tabular TDN are observed values from the literature review. Weiss TDN at 1x is predicted by Weiss et al. (1992) equation. Intestinal digestibilities for carbohydrate (A, B1, and B2) and protein (B1, B2, and B3) fractions are 100, 75, 20, 100, 100, and 80% respectively.
[a, b, c] Recommended ranges of degradation rates for carbohydrate A/B1, B2, and protein B3, respectively, are listed in Table 5.

Table 4 - Amino acid composition of typical tropical feeds (%CP).

Feed	MET	LYS	ARG	THR	LEU	ILE	VAL	HIS	PHE	TRP
1	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
2	0.83	6.13	4.92	3.81	6.85	5.30	4.03	1.71	4.36	1.05
3	1.22	3.21	2.44	3.30	6.40	3.13	Ñ-	0.63	4.18	1.84
4	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
5	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
6	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
7	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
8	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
9	1.28	8.23	4.28	4.70	12.75	1.35	8.40	5.16	7.02	4.70
10	1.78	3.36	4.76	3.53	9.62	5.94	6.05	2.06	5.52	1.40
11	1.30	7.00	––	4.70	7.00	6.10	5.80	2.00	3.80	1.40
12	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
13	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
14	1.33	3.33	4.67	2.67	4.67	3.00	3.67	3.00	1.00	0.67
15	1.50	3.67	5.17	3.17	4.61	2.69	4.50	1.87	2.80	1.10
16	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
17	1.12	1.65	1.82	2.80	10.73	2.69	3.75	2.06	3.65	0.37
18	1.92	3.27	4.71	3.94	12.98	3.85	5.19	2.98	1.92	3.37
19	0.68	3.47	3.54	3.26	6.24	3.47	4.49	1.32	4.06	3.97
20	1.38	3.84	7.93	3.08	5.32	3.21	4.23	3.11	2.73	0.98
21	5.30	5.18	11.69	4.34	11.20	3.01	5.42	2.53	4.34	3.61
22	5.30	5.18	11.69	4.34	11.20	3.01	5.42	2.53	4.34	3.61
23	1.43	4.34	11.19	3.49	5.97	3.42	4.79	3.22	4.45	1.30
24	0.63	3.85	10.40	3.45	6.33	3.77	5.27	3.14	5.85	1.74
25	0.73	6.02	6.39	5.00	9.26	6.01	7.14	2.62	6.32	1.84
26	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
27	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
28	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
30	2.05	5.56	4.85	4.72	8.41	4.25	6.59	1.8	5.34	2.2
31	2.05	5.56	4.85	4.72	8.41	4.25	6.59	1.8	5.34	2.2
32	2.05	5.56	4.85	4.72	8.41	4.25	6.59	1.8	5.34	2.2
33	2.05	5.56	4.85	4.72	8.41	4.25	6.59	1.8	5.34	2.2
34	2.05	5.56	4.85	4.72	8.41	4.25	6.59	1.8	5.34	2.2
35	2.05	5.56	4.85	4.72	8.41	4.25	6.59	1.8	5.34	2.2
36	2.05	5.56	4.85	4.72	8.41	4.25	6.59	1.8	5.34	2.2
37	2.45	7.1	5.89	5.94	10.76	5.11	7.54	2.28	6.44	2.96
38	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
39	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
40	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
41	1.80	4.40	4.00	4.20	6.70	3.90	4.50	2.70	4.20	2.40
42	1.40	6.70	6.40	4.60	9.00	5.00	5.80	2.70	5.40	4.50
43	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
44	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
45	0.84	5.60	8.28	2.52	5.46	2.43	3.67	1.44	3.03	0.00
47	0.84	5.60	8.28	2.52	5.46	2.43	3.67	1.44	3.03	0.52
48	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50

Feed	MET	LYS	ARG	THR	LEU	ILE	VAL	HIS	PHE	TRP
49	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
50	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
51	1.40	3.10	2.10	3.80	6.20	4.70	5.90	1.90	7.30	0.60
52	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
53	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
54	2.25	6.02	5.04	4.94	8.66	4.55	6.8	2.01	5.58	2.1
55	2.25	6.02	5.04	4.94	8.66	4.55	6.8	2.01	5.58	2.1
56	2.25	6.02	5.04	4.94	8.66	4.55	6.8	2.01	5.58	2.1
57	2.25	6.02	5.04	4.94	8.66	4.55	6.8	2.01	5.58	2.1
58	1.33	3.43	3.12	3.27	5.11	2.8	4.43	1.23	3.18	1.38
59	1.33	3.43	3.12	3.27	5.11	2.8	4.43	1.23	3.18	1.38
60	1.33	3.43	3.12	3.27	5.11	2.8	4.43	1.23	3.18	1.38
61	1.33	3.43	3.12	3.27	5.11	2.8	4.43	1.23	3.18	1.38
62	1.33	3.43	3.12	3.27	5.11	2.8	4.43	1.23	3.18	1.38
63	1.33	3.43	3.12	3.27	5.11	2.8	4.43	1.23	3.18	1.38
64	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
65	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
66	1.87	2.95	4.68	3.67	9.64	3.60	4.39	2.16	4.60	0.86
67	1.45	4.86	4.16	3.43	6.41	3.45	4.29	1.64	4.05	1.3
68	1.45	4.86	4.16	3.43	6.41	3.45	4.29	1.64	4.05	1.3
69	0.48	1.73	1.60	1.80	3.06	1.94	2.48	0.78	1.70	2.04
70	0.57	1.80	1.84	1.87	2.97	1.80	2.51	0.85	1.70	2.01
71	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
72	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
73	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
74	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
75	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
76	0.73	6.02	6.39	5.00	9.26	6.01	7.14	2.62	6.32	1.84
77	1.26	2.44	3.87	3.28	13.36	3.87	4.71	2.27	5.13	0.84
78	1.26	2.44	3.87	3.28	13.36	3.87	4.71	2.27	5.13	0.84
79	1.26	2.44	3.87	3.28	13.36	3.87	4.71	2.27	5.13	0.84
80	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
81	0.75	3.61	7.07	2.26	4.29	3.01	2.78	1.35	2.78	0.75
82	0.75	3.61	7.07	2.26	4.29	3.01	2.78	1.35	2.78	0.75
83	1.24	6.73	7.23	4.35	7.57	4.78	5.04	2.85	5.28	1.21
84	0.47	4.54	4.72	2.74	4.86	2.46	3.30	1.84	2.99	0.67
85	1.42	6.17	6.79	3.79	7.11	5.33	4.89	2.42	4.71	1.40
86	1.42	6.17	6.79	3.79	7.11	5.33	4.89	2.42	4.71	1.40
87	0.73	6.02	6.39	5.00	9.26	6.01	7.14	2.62	6.32	1.84
88	1.73	3.65	1.73	3.94	6.35	3.65	5.48	1.83	3.94	1.35
89	1.77	4.59	4.21	4.03	6.78	3.47	5.24	1.46	3.96	1.63
90	1.77	4.59	4.21	4.03	6.78	3.47	5.24	1.46	3.96	1.63
91	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
92	0.80	2.13	1.87	2.13	6.40	2.40	3.20	1.07	2.94	0.11
93	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
94	0.67	2.83	2.83	2.83	5.49	2.83	3.83	1.00	3.50	4.50
95	2.12	2.02	4.38	2.16	7.70	3.84	0.00	1.80	5.86	1.28
96	2.76	10.46	7.17	6.89	10.20	9.92	8.83	15.43	6.89	1.10

Table 5 - Ranges for carbohydrate and protein degradation rates categorized by the NDFIP content of grass forages[1]

NDFIP (%CP)	Degradation rate, %/h		
	Min	Mean	Max
5 to 20 (N = 5)			
CHO A/B1	18.6	26.8	34.8
CHO B2	7.9	8.3	8.6
Protein B3	0.3	3.6	6.3
21 to 35 (N = 10)			
CHO A/B1	8.3	17.7	25.5
CHO B2	4.2	6.7	8.2
Protein B3	0.1	5.0	10.5
35 to 50 (N = 6)			
CHO A/B1	9.8	13.1	18.4
CHO B2	3.4	6.2	7.4
Protein B3	5.2	6.8	9.9

[1] NDFIP = Neutral detergent fiber insoluble protein (%CP) and CHO = carbohydrate.

$$Y = a\left(1 - \exp^{[-b(X-c)]}\right) \qquad \text{Eq. (6)}$$

where Y is the residue (g) at time X (h), “a”, “b”, and “c” are parameters of the exponential equation. The parameter “a” is the asymptotic value of Y, “b” is the degradation rate (%/h), and “c” is the lag time (h).

A new approach to convert gas production models to an effective first-order rate constant for digestion has been presented by Pitt et al. (1999). To obtain this first-order rate, their model assumes a steady-flow rumen system combined with rates of intake and passage.

CONCLUSIONS

The TDN values predicted by the CNCPS model level 2 (with simulated rumen fermentation) and the Weiss et al. (1992) equations were similar, but differed from the tabular values. The CNCPS model provides two systems that can be used to predict feed biological values in each production situation, using actual feed composition. Although rigorous selection and standardization were used to develop the tropical feed library, some critical feed information on the degradation rates of the various carbohydrate and protein fractions, amino acid composition and mineral values were still hard to obtain. Published papers rarely report the information necessary to improve computer models such as feed composition (neutral and acid detergent fibers, lignin, soluble protein, non-protein nitrogen), animal characterization (breed, physiological stage, weights, performance), and environment (temperature, relative humidity). Further research is needed to provide more accurate values for these variables. Because most of the values used in these analyses are mean of different studies, it is recommended that actual chemical composition of feeds are obtained to enhance model predictions of animal performance.

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