Use of Equations to Predict the Nutritive Value of Tropical Grasses[1]

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Highlight

Literature values for the digestibility of tropical grass species were used to compute equations to predict apparent digestibility of crude protein and total digestible nutrients from proximate analyses. It was found that effective predictions could be obtained for the apparent digestibility of crude protein and that values varied considerably among individual grass species. Large differences were not found either among methods of preparation (i.e. silage, hay, fresh material) nor among species of animal used. The equations for TDN accounted for a minor part of the total variation and were of little value for prediction. The results are discussed in relation to the hypotheses underlying the various criteria used in the determinations.

Resumen

Se usaron valores de la literatura sobre digestibilidad de especies de pastos tropicales para computar ecuaciones para predecir la digestibilidad aparente de proteína cruda y los nutrientes digestibles totales utilizando datos de análisis proximales. Se encontró que podrían obtenerse ecuaciones efectivas para predecir la digestibilidad aparente de proteína cruda y que valores variaron considerablemente entre especies individuales de pasto. No se encontraron grandes diferencias ni entre los métodos de preparación (i.e. ensilaje, heno, material fresco) ni entre la especie de animal usado. Las ecuaciones para TDN proveyeron una menor parte de la variación total y fueron de poco valor para la predicción. Se discutieron los resultados como se relacionaron con algunas hipótesis que se hicieron con respecto de los varios criterios usados en la determinación.

The necessity to predict the nutritive value of various forages from a knowledge of their proximate composition has been appreciated for some time. This prediction may be particularly important where facilities for animal study are limited because of time and financial resources. Such equations relating chemical composition determined in various ways, to nutritive value have been suggested for the prediction of the apparent digestibility of crude protein (DCP) and total digestible nutrients (TDN) by various authors both for temperate climates (see, for example: Stohmann, 1869; Axellson, 1938; Schneider et al., 1951; Gaillard, 1962; Sullivan, 1964; Van Soest, 1965; Van Dyne, 1968; etc.), for the tropics (Duckworth, 1946; Butterworth, 1963; Bredon et al., 1963; Milford and Minson, 1965; etc.), and by Glover et al. (1957) for both temperate and tropical climates.

Where sufficient data are available to construct equations for individual grasses, these may be used to compare nutritive value of the grasses concerned under a wider range of conditions than those generally available for experiment. Equations are also of importance in the prediction of the nutritive value of grass products such as hays and silages which may be expected to differ somewhat from the original material and to compare results obtained for different animal species. The purpose of the present work was to use literature values to derive equations for the prediction of the apparent digestibility of crude protein and the content of TDN in tropical grasses both generally, and where sufficient data were available, specifically. Equations were also derived for hays and silages and to investigate interspecific differences among the animals used in the determinations.

Material and Methods

The data used were taken from an already prepared literature compilation (Butterworth, 1967a). Each value represented a mean for the number of animals used in the original trial. Readers interested in more detail should consult the reference cited.

Simple correlation coefficients were calculated among the following variables in order to investigate basic relationships: dry matter (DM), apparently digestible crude protein (DCP), TDN, crude protein (CP), crude fibre (CF), ether extract (EE), ash, % apparent digestibility of DM (DM_2), % apparent digestibility of EE (EE_2), % apparent digestibility of CP (CP_2), % apparent digestibility of CF (CF_2) and % apparent digestibility of NFE (NFE_2). The values so obtained were used to indicate possible solutions to obtain the least squares "best" value for the multiple regression equations. Computations were made on an IBM 1620 computer and the computer was programmed so that values which did not give a minimum value of F equal to 2.5 were eliminated.

Results

Values for the correlation coefficients between the different variables are given in Table 1. For

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Table 1. Values of simple correlation coefficients between various variables of tropical grasses.

	DM[1]	DCP	TDN	CP	CF	EE	NFE	ASH	DM_2	CP_2	CF_2	EE_2
DCP[1]	–.24											
TDN	–.31	.43										
CP	–.21	.96	.41									
CF	.27	–.51	–.35	–.51								
EE	–.35	.50	.41	.50	–.33							
NFE	.07	–.47	.01	–.46	–.33	–.28						
ASH	–.29	.49	–.16	.23	–.18	.12	–.61					
DM_2	–.27	.29	.94	.47	–.30	.37	–.09	–.09				
CP_2	–.25	.83	.55	.72	–.39	.45	–.36	.21	.60			
CF_2	–.22	.30	.77	.28	–.15	.17	–.17	.14	.71	.34		
EE_2	–.27	.24	.37	.19	–.15	.46	–.10	.08	.30	.34	.13	
NFE_2	–.35	.44	.89	.39	–.45	.39	.04	.02	.81	.51	.56	.33

[1] See text for explanation of abbreviations.

the regression equations, the best goodness of fit for all data was obtained with the following general models:

$$CP_2 = A_o + A_1 Log_e CP \qquad (1)$$

$$TDN = A_o + A_1 Log_e CP + A_2 CF + A_3 Log_e EE \qquad (2)$$

Data were classified according to species of grass (where more than 10 sets of data were available), species of animal used in the determinations, and as fresh material, hay or silage.

Table 2. Constants in the equation ($CP_2 = A_0 + A_1 \; Log_e \; CP$) for the prediction of apparent crude protein digestibility (CP_2) for various species of tropical grasses, hay, silage, and fresh material and their utilization by different livestock species.

Category	No. of samples	A_0	A_1	SE[1]	r^2
All data	465	– 31.56	39.83	1.40	0.64
Brachiaria mutica	20	– 12.73	33.80	3.70	0.82
Cenchrus ciliaris	20	– 0.40	25.82	5.49	0.55
Chloris gayana	41	– 42.38	43.90	4.17	0.74
Cynodon dactylon	14	– 33.96	41.66	5.30	0.84
C. plectostachyus	13	– 43.89	45.14	4.70	0.89
Digitaria decumbens	27	– 32.41	38.59	4.43	0.75
D. pentzii	11	– 2.29	28.33	7.64	0.60
Hyperrhenia rufa	11	– 37.78	46.35	8.70	0.76
Panicum maximum	40	– 29.29	41.81	6.96	0.49
Paspalum commersonii	20	–109.43	74.30	14.90	0.58
P. plicatulum	11	– 71.88	57.09	8.23	0.84
Pennisetum purpureum	40	17.88	19.50	2.30	0.65
Sorghum vulgare	14	– 35.59	47.14	9.57	0.67
Zea mays	14	– 88.55	67.76	16.35	0.59
Fresh material	315	– 18.88	39.07	1.75	0.61
Hay	104	– 32.32	39.40	2.01	0.79
Silage	34	– 32.95	36.72	8.00	0.40
Bos taurus	9	– 20.27	31.00	14.84	0.38
Bos indicus	55	– 32.27	43.11	4.64	0.62
Sheep	147	– 35.64	41.47	1.62	0.65
Bos spp. (unspecified)	48	– 13.08	31.07	3.68	0.61

[1] Estimate of standard error.

Values of the constants obtained in equations (1) and (2) for the various classes are given in Table 2 and 3 respectively. Values of r^2 indicating the percentage of the total variance contributed by the regression are also given in these tables.

Discussion

The use of correlation coefficients to discern basic relationships has been described as an inefficient tool by Van Soest (1967) and so it is shown to be in the present work where for example, despite a significant value of r (Table 1), crude fibre did not intervene in the general equation for the prediction of apparent digestibility of crude protein. Presumable interactions among various plant constituents are so high as to obscure mean-

Table 3. Constants in the equation ($TDN = A_0 + A_1 \; Log_e \; CP + A_2CF + A_3Log_eEE$) for the prediction of total digestible nutrients (TDN) for various species of tropical grasses, hay, silage, and fresh material and their utilization by different livestock species.

Category	No. of samples	A_0	A_1	A_2	A_3	r^2
All data	296	51.19	4.26	–0.25	5.12	0.27
Brachiaria mutica	20	53.85	—	18.65	—	0.44
Chloris gayana	29	33.54	8.01	—	4.53	0.49
Cynodon dactylon	8	26.16	—	0.76	8.26	0.76
C. plectostachyus	8	11.48	17.90	—	—	0.98
Digitaria pentzii	7	134.37	—	2.20	—	0.94
Hyperrhenia rufa	9	33.67	15.41	—	–12.74	0.74
Panicum maximum	17	18.09	14.92	—	8.81	0.53
Pennisetum purpureum	29	52.43	—	—	4.33	0.12
Zea mays	14	23.42	18.24	—	—	0.25
All fresh material	190	51.65	3.66	–0.25	6.85	0.30
All hays	78	39.47	6.44	—	—	0.18
All silages	17	76.97	—	–0.67	—	0.15
Bos indicus	26	49.82	—	—	10.43	0.25
Sheep	219	50.99	5.46	–0.32	4.96	0.35
Bos spp. (unspecified)	41	67.91	—	–0.43	—	0.08

ingful relations. Nevertheless, the failure of crude fibre to exert an effect is surprising in view of the results published by Glover et al. (1967) and Butterworth (1963). In view of the empirical nature of the determination of crude fibre in that it does not isolate either a meaningful chemical or nutritional entity, it is likely that differences in technique from laboratory to laboratory and wide variation in the grasses considered obscured any relationship which may be expected to exist. Quarterman (1961) has indicated that in the case of tropical forages where the apparent digestibility of the crude fibre is almost invariably higher than that of nitrogen free extractives, these fractions represent a different partition of cell wall components than is the case in plant materials from temperate zones. More sophisticated systems for the analysis of these components have been suggested (see for example, Van Soest, 1967) but unfortunately the only results which are available from tropical regions have been obtained using traditional methods.

The logarithmic form of the equation for apparent crude protein digestiblity is to be expected in view of the contribution of the minimum endogenous faecal nitrogen fraction which also accounts for the negative value for A_0 with consequent negative apparent digestibility values at low levels of crude protein content.

The utility of crude protein as a predictive factor has been criticized because of the wide variability which may exist due to differing relations of true protein and non-protein nitrogen particularly in highly fertilized grasses. It is not considered that this is of particular significance in the case of tropical grasses where little evidence that such wide variation exists because of relatively infrequent use of nitrogenous fertilizers (although Butterworth (1968) has indicated that where such intensive fertilizer application has taken place, the frequency distribution of protein values was not the same as for unfertilized grass).

When equations for individual grasses are considered (Table 2), the difference among values for apparent protein digestibility are striking both insofar as slope and constant are concerned. Such grasses as *Paspalum commersonii*, *P. plicatulum* and *Zea mays* are clearly inferior at low levels of protein while *Brachiaria mutica*, *Cenchrus ciliaris*, *Digitaria pentzii* and *Pennisetum purpureum* are superior. These extreme values should be regarded with caution however because of the high error generally associated with extrapolation. The slope of the lines for *Paspalum commersonii* and *Zea mays* indicate the superiority of these at higher protein levels. Differences among grasses emphasize the advantages of the use of equations for individual species. Values of r^2 indicate that for several species, accurate predictions may be made. There appears to be little difference in apparent protein digestibility among values for fresh material, hays and silages. The slight superiority of fresh material and hay over silage is probably due to protein insolubility caused by overheating during the process of silage making under tropical conditions.

When differences due to animal used in the determination are considered, the only valid comparison which may be made is between *Bos indicus* cattle and sheep as insufficient *Bos taurus* cattle were represented. The equations indicate a slight advantage in digestive efficiency for *Bos indicus* cattle over sheep although this was not large enough to be of practical significance. This supports the general supposition that the digestive efficiency of various species may be considered equal, and suggests that it is also valid for tropical conditions.

It should be noted that in view of the small numbers of data involved in the case of the individual species, these values were confounded with type of grass (i.e., hay, silage, or fresh material) and with animal used. However, in view of the smallness of the effects due to these causes it is considered that differences among species were not obscured.

Equations relating proximate analysis values to TDN are of little value for purposes of prediction because of the generally low values of r^2. In the general case only 27% of the total variance can be explained by the equation. In general the tendency is for the value of TDN to be positively influenced by crude protein and ether extract content and negatively influenced by crude fibre content. There are so many exceptions to these generalizations however as to render them of little value.

Lack of predictability of TDN reflects the arbitrary nature of the Weende system of proximate analysis as mentioned earlier but also reflects the *ad hoc* character of the concept of TDN in ruminants and the hypotheses upon which it is based. Many factors also influence digestibility, and thus TDN, apart from chemical composition. The most important of these is level of intake but other factors include silification, the presence of toxic factors, etc. As the values used to calculate prediction equations in the present work were derived from many different laboratories using different analytical methods, species of animals, levels of intake, etc., it is hardly surprising that low values of r^2 were obtained.

It may be concluded from the above discussion that in many cases the apparent digestibility of crude protein may be predicted with considerable accuracy from the content of protein in the grass. However, the accuracy of prediction of TDN from proximate analysis data was in most cases extremely low. It may be concluded that in tropical regions attention should be paid to more sophisticated methods of determining plant constituents and also to methods other than TDN of evaluating energy utilization by the animal; this could include the determination of digestible or metabolizable energy. Butterworth (1967b) has shown that there is more usually a deficiency of protein than energy in grasses under tropical conditions and the prediction of this factor is thus of more general importance in the assessment of the production potential of land used for intensive pasture and forage production.

In any event, the present necessity under tropical conditions is to collect data on animal production under defined systems of grazing management and to relate these to digestibility rather than vice versa.

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