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Assessment of Energy Content of Some Tropical Concentrate Feeds of Ruminants using Model of National Research Council - 2001

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Abstract

An experiment was conducted to predict the energy content (TDN- total digestible nutrients, DE- digestible energy and ME- metabolizable energy) of some commonly used tropical concentrate feeds of ruminants using the summative approach model of National Research Council (NRC) 2001, which is based on chemical composition values of feeds rather than the values of digestion trial. Fourteen concentrate feeds (six grains, three oilcakes, two protein meals, three agro-industrial byproducts) were analyzed for their proximate principles, fiber components, neutral detergent insoluble nitrogen (NDIN), acid detergent insoluble nitrogen (ADIN) and the TDN was then calculated. DE and ME contents were estimated from the TDN value. Three types of total mixed rations (TMRs) were prepared comprising 40% concentrate mixture, 40% green fodder (berseem- *Trifolium alexandrinum*) and 20% wheat straw (*Triticum aestivum*) on dry matter basis (DMB). These TMRs were fed to three groups of growing Sahiwal calves (average body weight of 173.66±12.54 kg and average age of 12 – 18 months). The predicted TDN values of the TMRs as per NRC (2001) were 60.21, 60.14 and 60.53% of DM, respectively. The TDN values obtained by the results of the digestion trial (61.11, 61.98 and 60.56%) were in conformity with that of in vitro results. Therefore, it was concluded that the TDN based model of NRC (2001) can be successfully implemented to predict the energy density of tropical ruminant feeds. The predicted TDN values of concentrate feeds were also more or less in close proximity of their standard TDN values.

Keywords: Energy Content, NRC- 2001 Model, Ruminants, TDN, Total Mixed Rations

1. Introduction

Energy content of a feed is the most important criteria in determining its feeding value in ruminants. So correct assessment of feeds for their energy density is a primary requisite for predicting the performance of ruminants, more particularly in dairy animals[1]. Sufficient dietary energy is an important factor for prevention of negative energy balance and other metabolic disorders in lactating animals[2]. Similarly increased dietary energy density improves weight gain[3] and feed efficiency[4] in lactating cows. Gross energy (GE) of feedstuffs can be evaluated by instruments like bomb calorimeter, near infra red spectroscopy (NIRS) etc. But these are very costly and often not practicable. The in vitro gas production technique is also a very potential method for expressing energy content of feeds in terms of ME[5-6]. But this technique requires the maintenance of fistulated animals, which is

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often not feasible under ethical point of view. The more conventional method of expressing the energy content of feeds is estimating their TDN content involving a digestion trial, in which the faecal loss of various nutrients are taken into account for arriving at the digestible nutrients. These methods also have several drawbacks such as laborious, high cost and time consuming. The inclusion of digestible crude fiber (DCF) and digestible nitrogen free extract (DNFE) for calculation of TDN is also erroneous as CF of a feed is always underestimated by proximate analysis. The data pertaining to TDN values of tropical feeds available is still based on the proximate analysis and in vivo digestibility studies[7]. With emergence of sophisticated ruminant nutrition models like NRC[8], AFRC[9], CNCPS[10] the feed analytical techniques have improved manifold, thus several prediction equations have come up for predicting the energy values of ruminant feeds. One of such prediction model to calculate the TDN values of feeds was developed by Weiss et al.[11] which included both proximate and detergent system of feed analysis. The major change of the model was inclusion of digestible non fibrous carbohydrate (dNFC) and digestible neutral detergent fiber (dNDF) in place of DNFE and DCF. There was also provision for a correction factor in the form of metabolic faecal TDN from the summative values of truly digestible nutrients, which makes the model logical and scientific. This model was accepted by NRC[8] for evaluating feed TDN values and the energy values of DE and ME were estimated from the equations of NRC[12]. Very few attempts were made to predict the TDN values of tropical feeds using this model. Kishore and Parthasarathy[13] evaluated TDN content of twenty four tropical forages and tree leaves using this summative approach of NRC[8].

This study is, therefore, aimed at predicting the TDN values of some common concentrate feeds using the prediction equations of NRC[8] and to validate these equations by comparing the predicted values with that obtained by digestion trial.

2. Material and Methods

2.1 Ethical Approval

The experimental design and plan of the present study were duly approved by the Institution Animal Ethics Committee of National Dairy Research Institute (NDRI), Karnal, Haryana.

2.2 Experimental Feeds and Diet Formulation

Fourteen concentrate feeds (six grains, three oilcakes, two protein meals, three agro-industrial byproducts) were collected from local market area of Karnal from at least five different localities. The samples were thoroughly mixed and a representative sample of about 100 g was pooled for analysis. They were dried to a constant weight in hot air oven at 60^0 C and ground through 1 mm sieve using electrically operated willey mill. Three TMRs (TMR I, II and III) were prepared taking concentrate mixture, berseem green and wheat straw at a ratio of 40: 40: 20 (on DMB), which were designed to have three different levels of dietary protein i.e. 15, 13.5 and 16.5% of DM. The TMRs differed only in the composition of their respective concentrate mixtures (C I, II and III). They were evaluated in vitro as that of the concentrate feeds. In vivo analysis of these TMRs were done by using fifteen male Sahiwal calves of 12-18 months of age (divided into three groups basing on their body weight) to estimate DM intake and digestibility of nutrients to arrive at TDN contents of the TMRs and to compare it with the in vitro predicted values.

2.3 Animal Trial

The digestion trial was carried out at the animal experiment premises of National Dairy Research Institute, Karnal, Haryana, India. The animals were assigned to dietary treatments (T I, T II and T III) randomly within groups to evaluate the response. All animals were housed in individual pens under similar environmental conditions and offered feed and water individually so as to estimate daily feed and water intake by each animal separately. The feeding trial lasted for 90 days. An initial adaptation period of three weeks (21 days) were given to the animals in pens, during which dry matter intake (DMI) was measured. Animals were shifted into the metabolism shed three days prior to the metabolism trial for their adaptation to the surroundings. The calves were weighed before and after the trial consecutively for two days. They were offered their respective TMRs ad lib. Fresh drinking water was provided thrice a day, and the quantity was measured each time to calculate the total water intake. The animals were weighed consecutively for two days on every fortnight interval till the end of the growth trial and corresponding DMI (kg/d) and DMI (kg/100 kg BW/d) by individual animal were also recorded. TMRs offered to and refused by individual animal were weighed daily throughout the metabolism trial to assess their daily as such intake. The TMR samples offered (Diet T I, T II and T III) were daily taken for DM estimation during metabolism trial. These samples were pooled at the end of the collection period and ground to pass through 1 mm sieve and stored in air tight containers. Daily residue left was weighed and treated the same manner as that of the TMRs to determine the intake of nutrients. Faeces voided during 24 h was collected daily for seven days and weighed at 9:00 hr daily. After thorough mixing, an approximately 2% of total sample on weight basis was kept for DM estimation. Dried pooled dung samples were ground to pass through 1 mm sieve size and stored in air tight container.

2.4 Chemical Analysis

Proximate principles of the test feeds, TMRs and faecal samples (DM – dry matter, OM – organic matter, EE – ether extract, CP – crude protein and total ash) were estimated as per the methods of AOAC[14]. Fiber components such as NDF (neutral detergent fiber), ADF (acid detergent fiber), cellulose, hemicellulose and ADL (acid detergent lignin) were analyzed as per the procedures of Van Soest et al.[15]. Neutral detergent insoluble crude protein (NDICP) and acid detergent insoluble crude protein (ADICP) content of feeds were evaluated as per Licitra et al.[16]. Non fibrous carbohydrate (NFC) content was calculated by difference using the equation of Van Soest[17]. The digestibility coefficients of nutrients were arrived from their respective intake and faecal outgo values and the sum of all the digestibility coefficient values gave the in vivo TDN values of TMRs.

2.5 Prediction of TDN, DE and ME Values

The values of proximate analysis and fiber analysis were used in the following equations of NRC[8] to predict the truly digestible (td) nutrients of the test feeds and then the digestibility values were summed up to arrive at the TDN content of the feeds.

NFC = 100 - [CP + EE + ash + (NDF - NDICP)]

td NFC = 0.98 × {100 - [CP + EE + ash + (NDF - NDICP)]}× PAF, where

PAF = Processing adjustment factor, 1 for most of the feeds.

$tdCP_{forage} = CP \times \exp[-1.2 \times (ADICP\ CP)]$

$tdCP_{concentrate} = [1 - (0.4 \times (ADICP\ \ CP))] \times CP$

td FA (fatty acid) = FA (FA = EE -1, if EE < 1, then FA =0)

td NDF = 0.75 × (NDFn -L) × $[1 - (L\ NDFn)^{0.667}]$, where

L = Acid detergent lignin and NDFn= NDF - NDICP

The TDN values were predicted by summing up the truly digestible nutrients. A subtraction factor of 7 in the form of metabolic faecal TDN was included in the equation as per the suggestions of Weiss et al.[11]. So the predicted TDN values were obtained as follows:

TDN (%) = td NFC + td CP + (td FA × 2.25) + td NDF - 7

The energy values of DE and ME were estimated using the following equations of NRC[12].

DE (Mcal/kg) = 0.04409 × TDN (%)

ME (Mcal/kg) =1.01 × DE (Mcal/kg) - 0.45

The energy values in Mcal/kg were converted to MJ/kg by using the multiplication factor 4.184 as 1 Mcal = 4.184 MJ.

2.6 Statistical Analysis

The obtained results were subjected to one way analysis of variance (ANOVA) by SPSS version 16.0 [18] for Windows and means were compared by least significance difference (LSD) test at 5% level of significance ($p < 0.05$).

3. Results

3.1 Chemical Composition of Feeds

Chemical composition and fiber fractions of the test feeds, concentrate mixtures and TMRs are presented in Table 1. Oilcakes and protein meals contained higher CP ($P < 0.05$) followed by agro-industrial byproducts and grains. Rice polish (RP) contained much higher EE (11.13%) than other feeds ($P < 0.05$). Among test feeds, cotton seed cake (CSC) contained highest NDF (50.91%) and soybean meal (SBM) contained lowest (17.72%) NDF ($P < 0.001$). All grains showed lower ADF values than rest of the feeds ($P < 0.05$). The ADICP content represents that fraction of feed protein which is neither available to microbes nor to the animal in case of ruminants. ADICP content was found to be higher in feeds like guar meal (GM), deoiled rice bran (DORB), RP and mustard oil cake

Table 1. Chemical composition of concentrate feeds, concentrate mixtures and TMRs (% DM)

Feeds	CP	EE	Ash	NDF	ADF	HC	Cellulose	ADL	NDICP	ADICP
Grains										
Maize	10.28	5.39	2.30	24.62	7.04	17.58	4.72	2.07	1.97	0.45
Wheat	13.11	1.94	2.36	17.77	4.47	13.30	2.63	1.56	3.71	0.65
Barley	10.99	1.85	4.17	40.12	9.72	30.40	5.51	3.27	2.99	0.43
Oat	9.82	4.83	3.26	24.93	8.51	16.42	5.27	2.88	2.07	0.36
Sorghum	9.99	3.45	2.84	27.38	7.25	20.13	5.52	1.47	1.96	0.51
Bajra	12.62	5.39	2.39	38.42	5.35	33.07	3.27	1.33	2.16	0.65
Oilcakes										
GNC	40.66	7.59	6.13	23.67	18.30	5.37	13.36	4.19	2.68	0.86
MOC	38.24	7.87	4.78	22.16	18.46	3.70	14.43	3.37	3.16	2.02
CSC	26.00	8.00	4.58	50.91	37.34	13.57	27.57	8.50	2.26	1.23
Protein meals										
SBM	45.14	1.87	8.43	17.72	9.77	7.95	7.86	1.16	9.36	0.96
GM	41.32	1.11	5.63	33.21	19.28	13.93	18.00	1.08	10.25	2.90
Agro-industrial byproducts										
WB	15.68	2.92	5.48	39.86	11.48	28.38	8.13	2.84	4.11	0.68
DORB	13.47	1.66	9.47	47.93	17.64	30.29	10.33	6.39	6.30	2.53
RP	12.15	11.13	15.34	35.27	18.45	16.82	11.07	6.85	5.44	2.44
Concentrate mixtures										
C I	18.09	4.30	7.13	29.64	11.46	18.18	6.84	4.26	2.61	0.68
C II	14.44	4.12	7.31	33.25	11.26	21.99	6.98	3.30	3.41	0.75
C III	21.67	4.57	7.47	32.60	13.07	19.53	7.82	4.06	3.26	0.76
Total Mixed Rations (TMRs)										
TMR I	14.97	3.63	10.33	54.38	34.99	19.39	22.84	6.47	11.36	2.06
TMR II	13.51	3.45	9.24	56.15	36.43	19.72	24.30	6.57	10.72	2.04
TMR III	16.52	3.76	11.78	52.35	34.89	17.56	21.87	6.12	12.61	2.03

CP: Crude protein, EE: Ether extract, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, HC: Hemicellulose, ADL: Acid detergent lignin, NDICP: Neutral detergent insoluble crude protein, ADICP: Acid detergent insoluble crude protein, GNC: Groundnut cake, MOC: Mustard oilcake, CSC: Cottonseed cake, SBM: Soybean meal, GM: Guar meal, WB: Wheat bran, DORB: De-oiled rice bran, RP: Rice polish,

(MOC). Feeds like CSC, DORB and RP contained higher ADL content ($P < 0.05$). The CP content of the concentrate mixtures were 18.09, 14.44 and 21.67%, respectively while the same value for the TMRs were 14.97, 13.51 and 16.52, respectively. NDF content of the concentrate mixtures and TMRs were 29.64, 33.25, 32.60% and 54.38, 56.15, 52.35%, respectively.

3.2 Predicted Energy Values of Feeds

Digestible nutrients and energy values of the test feeds, concentrate mixtures and TMRs are presented in Table 2. TDN content of all grains was recorded more than 80% except barley, which recorded 71.05% TDN. DE and ME content of all grains were similar except barley, which had slightly lower value ($P < 0.001$) of DE and ME. Among oilcakes & meals, GNC and MOC had higher TDN content with CSC having lowest (67.48%) TDN value ($P < 0.05$). The trend in TDN content was directly reflected in the DE and ME content of feeds. Wheat bran contained highest (72.23%) TDN value followed by rice polish (68.48%) and DORB (58.91%) among agro-industrial byproducts ($P < 0.001$). The predicted TDN values of concentrate mixtures were 72.92, 72.89 and 72.50%,

Table 2. Digestible nutrients and energy values of concentrate feeds, concentrate mixtures and TMRs (% DM)

Feeds	td NFC	td CP	td FA	td NDF	TDN (% DM)	DE (MJ/kg)	ME (MJ/kg)
Grains							
Maize	58.19	10.10	4.39	12.30	83.48	15.40	13.68
Wheat	67.16	12.85	0.94	7.21	82.34	15.19	13.47
Barley	44.93	10.82	0.85	20.38	71.05	13.09	11.34
Oat	58.06	9.67	3.83	11.22	80.56	14.85	13.14
Sorghum	57.14	9.78	2.45	15.29	80.72	14.89	13.15
Bajra	42.47	12.36	4.39	23.31	81.03	14.93	13.22
Oilcakes							
GNC	24.13	40.31	6.59	8.30	80.57	14.85	13.14
MOC	29.51	37.43	6.87	8.02	83.42	15.39	13.64
CSC	12.51	25.51	7.00	20.71	67.48	12.47	10.71
Protein meals							
SBM	35.48	44.76	0.87	3.97	79.15	14.60	12.84
GM	28.41	40.16	0.11	14.28	76.09	14.01	12.30
Agro-industrial byproducts							
WB	39.36	15.41	1.92	20.13	72.23	13.30	11.59
DORB	33.11	12.45	0.66	18.85	58.91	10.87	9.08
RP	30.91	11.47	10.13	10.60	68.48	12.63	10.87
Concentrate mixtures							
C I	42.78	17.82	3.30	12.10	72.92	13.47	11.71
C II	43.40	14.14	3.12	15.33	72.89	13.43	11.67
C III	36.22	21.37	3.52	13.90	72.50	13.39	11.63
Total Mixed Rations (TMRs)							
TMR I	27.49	14.14	2.63	19.66	60.21	11.08	9.33
TMR II	27.81	12.69	2.45	21.12	60.14	11.08	9.33
TMR III	27.65	15.70	2.76	17.98	60.53	11.17	9.41

respectively, while the TMRs were predicted to contain 60.21, 60.14 and 60.53% TDN, respectively.

3.3 In vivo Digestion Trial

The findings of the digestion trial with growing Sahiwal calves to obtain in vivo results regarding digestible nutrients of the TMRs are presented in Table 3. DM digestibility was almost similar in three groups i.e. 61.23, 61.59 and 61.03% for T I, T II and T III, respectively. Same was the case in OM digestibility, which recorded 63.70, 64.56 and 63.30% for T I, T II and T III, respectively. CP digestibility for T II (58.12%) and T III (66.11%) differed significantly from each other, however they were not statistically different from that of T I (61.40%). Digestible nutrients however were significantly different among all three groups except digestible NFC. Digestible CP (DCP) value was highest (10.92%) in T III followed by T I (9.19%) and T II (7.85%).The TDN (%) content of the TMRs as revealed form the digestibility data were 61.11, 61.98 and 60.56%, respectively.

4. Discussion

4.1 Chemical Composition of Feeds

Kamble et al.[19] reported similar CP values for maize, barley and wheat grain as that of present study. Mondal et al.[20] reported higher value of CP for SBM (54.81%) and lower value of CP for MOC (33.18%) than the present

Table 3. Nutrient digestibility (%) and nutrient intake by Sahiwal calves

Parameters	TMR I	TMR II	TMR III
Initial BW (kg)	171.94±12.33	175.54±11.35	173.52±13.89
Metabolic BW (kg W0.75)	47.39±2.55	48.15±2.32	47.69±2.91
DM intake (g/day)	5302.39±301.01	5470.98±308.72	4909.32±365.42
(kg % BW)	3.09 ± 0.07	3.12 ± 0.06	2.84 ± 0.09
(g/ kg W0.75)	111.87^{ab} ±1.55	113.48^{a} ±2.14	102.76^{b} ±3.18
CP intake (g/day)	806.49±45.78	752.64±42.47	817.50±60.85
(g % BW)	471.41±10.75	429.77±8.40	473.20±15.23
Nutrient digestibility (%)			
DM	61.23±1.36	61.59±1.76	61.03±0.74
OM	63.70±1.89	64.56±1.37	63.30±0.99
CP	61.40^{ab} ±2.41	58.12^{b} ±1.96	66.11^{a} ±0.73
EE	75.45±1.26	75.05±0.85	77.59±0.52
NDF	55.19±2.14	58.13±1.48	53.24±1.12
ADF	52.95±1.18	55.97±1.13	51.12±1.13
NFC	73.21±1.64	71.83±1.46	74.69±1.09
Digestible nutrients (%)			
Dig. CP	9.19^{b} ±0.02	7.85^{c} ±0.02	10.92^{a} ±0.01
Dig. FA	1.98^{b} ±0.01	1.84^{c} ±0.01	2.14^{a} ±0.02
Dig. NDF	30.01^{b} ±0.13	32.64^{a} ±0.13	27.87^{c} ±0.30
Dig. NFC	17.45±0.16	17.36±0.17	16.95±0.36
TDN	61.11^{b} ±0.03	61.98^{a} ±0.03	60.56^{c} ±0.05
Digestible nutrient intake			
DCP intake (g/day)	495.75 ± 27.60	424.54 ± 24.26	536.79 ± 39.92
TDN intake (kg/day)	3.24 ± 0.18	3.39 ± 0.19	2.97 ± 0.01

Means bearing different superscripts in the same row differ significantly. (* $P < 0.05$)

study. Gupta et al.[21] reported higher value of CP for CSC (30.28%). Addass et al.[22] found exceptionally higher CP content (41.00%) and lower EE content (1.50%) in CSC. Hamid et al.[23] reported similar CP values for maize grain and wheat bran, but the value for SBM was significantly higher (49.2%) than the present study. This research work also indicated comparable EE values for maize grain and wheat bran, but higher EE value for SBM than the present findings. Higher NDF content in Barley (40.12%) and Bajra (38.42%) among grains was most probably due to their fibrous outer seed coat. Higher NDF content in CSC (50.91%) was mostly because of process of undecortication, which was also supported by findings of Tolla[24] and Viana et al.[25]. As expected all agro-industrial byproducts had higher NDF content. Tahir et al.[26] reported similar values of NDF (33%) and ADF (18%) for rice polish as that of present study, but the corresponding values for wheat bran (51% and 15%) were relatively on higher side. Reports of Dutta et al.[27] indicated higher NDF and ADF values for wheat bran and rice polish than present findings. ADICP content of grains as reported by Lanzas et al.[28] was almost comparable to present findings except that of sorghum and wheat, which showed higher (1.9%) and lower (0.1%) values, respectively. Nutrient composition of feeds as enlisted in NRC[8] suggested similar, but lower values of ADICP for oilseed cakes. However reports of Kamble et al.[19] and Gupta et al.[21] were very much comparable to present findings. The variations in the chemical composition of feeds among several reports may partially be attributed to the factors like oil extraction assay, stage and environment of growth, variety, maturity level during analysis, soil status of the area concerned etc.

4.2 Predicted Energy Values of Feeds

TDN, DE and ME values of grains as reported by NRC[8] were similar to that of present findings, but the TDN value of barley as predicted in this study was lower than that of NRC[8]. The low TDN value of barley might have been due to its high lignin (3.27%) and low EE (1.85%) content among grains. Feed library of CNCPS[10] reported similar TDN, DE and ME values as that of present study, but the TDN value of oat was slightly lower as compared to the present findings. NRC[8] reported comparable values of TDN, DE and ME except MOC, which was reported to have less TDN than that of present results. CNCPS[10] reported higher value of TDN for CSC, but similar values of TDN for others as that of present findings. The lower TDN value of CSC (67.48%) as predicted in this study can be attributed to its high NDF (50.91%) and lignin (8.50%) content among oilseed cakes. In contrast to present study, Mlay et al.[29] reported higher (76.5%) TDN value for CSC. The TDN values for wheat bran and rice bran were determined by Tahir et al.[26] as 70%, which were very comparable to the present findings (72.23% and 68.48%, respectively). However Mlay et al.[29] reported much less (51.9%) TDN value for rice bran. The ME (MJ/kg DM) content of maize grain (13.3) and SBM (12.1) estimated by Hamid et al.[23] was similar, but slightly less than the present predicted values (13.68 and 12.84), however the predicted value for wheat bran (11.59) was higher than that reported by Hamid et al.[23]. The predicted TDN values of concentrate feeds are also in close proximity with the reports of Ranjhan[30].

4.3 In vivo Digestion Trial

Girdhar et al.[31] evaluated the TDN content of five diets (five types of concentrate mixture with 20.51, 19.24, 23.30, 21.95 and 20.51% CP along with oat green and wheat straw) offered to five groups of Frieswal bull calves as 61.79, 62.10, 61.63, 62.10 and 62.14%, respectively. The DCP values of above five diets were 6.80, 7.01, 8.48, 8.12 and 7.00%, respectively. These results were quite comparable to present findings. The TDN values (%) of TMR I (60.21), TMR II (60.14) and TMR III (60.53) predicted from the equations of NRC [8] are in agreement with the values of digestion trial. Shahzad et al.[32] recorded DM digestibility of 60.17, 58.83, 59.00 and 60.17% in 12-15 month old Nili Ravi buffalo calves with four different diets having 10.5, 12.20, 13.80 and 15.55% CP. Digestibility of CP increased linearly with increase in diet CP i.e. 69.33, 69.83, 70.33 and 70.83%, which corroborated with the findings of present study.

5. Conclusion

As it was possible to predict the energy content of ruminant feeds (TDN, DE and ME) from their proximate and fiber analysis by following the summative approach of NRC[8], it was therefore concluded that the above prediction model could be used as a reliable, rapid, accurate and inexpensive method in place of conventional energy estimation procedures.

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