# Deriving Nutrient Requirements of Lactating Indian Cattle under Tropical Condition Using Performance and Intake Data Emanated from Feeding Trials Conducted in Different Research Institutes

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**ABSTRACT :** Data from 24 feeding trials conducted on lactating cattle from different institutes across India were subjected to regression analysis to derive requirements of ME, TDN, CP and DCP for maintenance, milk production and body weight gain. Maintenance requirements for ME, TDN, CP and DCP were 598 KJ, 39.5 g, 6.27 g and 2.90 g/kg $W^{0.75}$, respectively and the corresponding requirements for production of 1 kg 4% FCM were 5,023 KJ, 332 g, 82 g and 58 g. The corresponding requirements for one g gain in BW were 27 KJ, 1.78 g, 0.44 g and 0.19 g. Regression equations had high $R^2$ values (0.67 to 0.90) and the equations (F value) as well as coefficients were highly significant (p<0.001). Regressed values were used to develop feeding standards. Derived values matched well with the actual intake versus performance of animals under diverse feeding conditions. The new standards so derived predicted requirements and intake of nutrients for different production levels better than existing feeding standards; as these are based on a more thorough analysis of a larger database, the new feeding standards will be appropriate for wide use in India. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 6 : 769-776)***

**Key Words :** Feeding Standards, Cattle, Protein Requirements, Energy Requirements, Lactation, Tropical Conditions

## INTRODUCTION

Large ruminants such as cattle continue to play an important role in the livestock production system in India. Indian cattle breeds are of smaller mature body size, grow at slower rate and produce a low quantity of milk as compared to the breeds found in temperate countries. However, the breeds are hardy, and well adapted to heat stress and poor quality diets, a situation which is characteristic of tropical countries. The nutrient needs of these animals probably differ from those prescribed in the feeding standards of temperate countries (NRC, 1989; AFRC, 1990) because of differences in genetic makeup, mature body size and growth rate, quality of feeds, climatic conditions and differences in efficiency of nutrient utilization. Very few studies have been conducted so far to measure nutritional requirements of tropical breeds, which is perhaps the most important consideration to obtain the best efficiency in any type of production system. Knowing the properties of the feed is equally important. Singh et al. (2003) reported that elevating feeding plane by 20% above NRC (1989) feeding standards during 60 d prepartum to 120 d postpartum period improved productive and reproductive performance of high yielding Indian cows. The appropriate feeding standards for these animals are not yet clearly defined, there being wide differences (as high as 40%) in nutrient requirements prescribed by existing feeding standards. Although western countries have adopted RDP and UDP system and NE for expressing protein and energy requirements, India and many tropical countries still continues to use CP and DCP, TDN or ME for expressing nutritive values of feeds and feeding standards. Most of the available publications on feeding trials on lactating cattle in India reported nutritive values of feed in terms of CP, DCP, TDN and ME.

The feeding standards for cattle, which are currently being followed in India (Kearl, 1982; ICAR, 1998), are based on only a few feeding trials. As these standards were developed from a small database, they do not reflect requirements for widely different planes of nutrition, quality of feed or individual variations under the diversified tropical conditions prevailing in India. An optimum milk production, growth rate and feed efficiency according to inherent genetic potentiality of a particular category of animal can be achieved only through accurate evaluation of their nutrient needs. Regression analysis of feeding trial data provides estimates of nutrient requirements of producing animals kept under normal farm feeding condition and hence such approach has been widely used (Abate, 1989; Walter and Mao, 1989; Solis et al., 1991; Udeybir and Mandal, 2001; Paul et al., 2002; Paul et al., 2003). Keeping these in view, the present study was undertaken to determine energy and protein requirements of lactating cattle using the combined nutrient intake and performance data of almost all of the experimental feeding

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trials conducted so far in India under diversified tropical feeding conditions.

## MATERIALS AND METHODS

### Data collection

The data on intake of DM, ME, TDN, DCP or CP, BW, ADG, roughage and green forage percentage in the ration generated through experimental feeding trials conducted on lactating cattle in different research institutes of India were collected from 47 published reports. However, data from 23 studies were subsequently excluded, because the information in these reports was incomplete with respect to one or more of the essential variables such as body weight, milk yield, milk fat percentage, weight change and nutrient intake. Only those data were admitted that contained complete information with respect to BW, FCM production, weight changes and nutrient intake. Finally, data from 24 studies (Hassan et al., 1985; Reddy et al., 1991a,b; Sampath et al., 1992; Pachuri and Majumdar, 1994; Talpada et al., 1994; Pathak and Pande, 1995; Ramchandra and Sampath 1995; Srivastava and Veenamani, 1995; Talpada et al., 1995; Maity et al., 1996; Reddy et al., 1996; Srinivas and Verma, 1996; Maity et al., 1997; Prasad and Tomar, 1997; Puranik et al., 1997; Saseendaran and Thiagrajan, 1997; Sihag et al., 1997; Dogra et al., 1998; Pathak et al., 1998; Kalbande and Thomas, 1999; Sahoo et al., 1999; Srinivasulu et al., 1999a,b) representing 72 different dietary treatment groups were used in the present study. These studies were conducted across a wide range of locations and conditions in India. The ranges of values of different parameters are summarized in the result section. In most of the trials, energy intake was expressed in TDN units and protein as CP or DCP units. In the present study, metabolisable energy (ME) was calculated from TDN values using a factor of 1 kg TDN=15.129 MJ ME. The 4% fat-corrected milk (FCM) yield was calculated from milk yield and fat percentage data using standard formulae. Henceforth, unless otherwise stated, FCM will mean 4% FCM.

### Animals and feeding management in the feeding trials

The type of cattle included crossbreeds (HF×Haryana, Sahiwal×Jersey, Karan Swiss, Karan Fries, Jersey×HF× Indigenous, Tharparkar×Jersey, Jersey×Red Sindhi, Haryana×Jersey, Ongole×Jersey×HF, Brown Swiss× Haryana, Trisur×Jersey, Ongole×Jersey, Kankrej×Jersey, Ongole×Holstein), indigenous pure breed (Kankrej) and indigenous nondescript. In all of the feeding trials animals were fed in groups of 4-6 animals *ad libitum* from a weighed allowance of feed. The roughage source included paddy straw, mustard green, berseem, maize fodder, oat fodder, sorghum silage, wheat straw, mixed dried grass, sorghum straw, barley fodder, sorghum fodder, oat hay, groundnut haulm, cotton seed hulls, sunflower straw, green cow pea, pearl millet straw, napier grass, pasture grass, cowpea hay, *Cenchrus* hay, *Gliricidia* leaves, urea treated paddy straw, gram straw, *Setaria anceps* leaves, *Leucaena leucocephala* leaves, *Robinia pseudoacacia* leaves and green para and guinea grass. The concentrate components included maize, wheat, ground nut cake, soya protein, soya flakes, mustard cake, cotton seed cake, urea mineral molasses block, sunflower cake, single cell protein, mahua cake, wheat bran, rice bran (deoiled), urea, fat, barley, molasses, rice polish, *Leucaena leucocephala* seed, cocoa pod shell, cocoa bean husk, etc. All animals were supplemented with a mineral mixture in the concentrate components. Feed intake was recorded daily in all the experiments. BW was recorded every 2 weeks. Digestion or metabolism trials were also conducted to ascertain the nutritive value of rations in all trials. Environmental parameters were not recorded in any of the studies. However, on the basis of the geographical locations of the experimental stations (experiment stations are between 13°N and 29°N latitude), it can be inferred that the climate was tropical, with hot and humid weather for most of the year, yearly temperature ranges from a minimum of 4°C to a maximum of 48°C.

### Estimation of nutrient requirements

Pearson correlation coefficient computed on the data showed that ME or TDN intake was significantly correlated with MBW (r=0.66; p<0.001), FCM (r=0.88; p<0.001) and ADG (r=0.27; p<0.05). A significant positive association was also observed between CP intake and MBW (r=0.73; p<0.001) or between CP intake and FCM (0.83; p<0.001) or between CP intake and ADG (r= 0.27; p<0.05). DCP intake was also highly correlated with MBW (r=0.65; p<0.001) and FCM (0.93; p<0.001). There was very high positive correlation (r=0.82; p<0.001) between ME or TDN intake/kg $W^{0.75}$ and FCM/kg $W^{0.75}$. CP intake/kg $W^{0.75}$ was also highly correlated (r=0.76; p<0.001) with FCM/kg $W^{0.75}$ as were DCP intake/kg $W^{0.75}$ and FCM/kg $W^{0.75}$ (r=0.88; p<0.001). On detection of significant relationship between nutrient intake and performance variables (BW, FCM and ADG), the data were subjected to regression analysis to develop nutrient requirement prediction models.

The experimental data were subjected to regression analysis using the following model:

$$Y=a+b_1X_1+b_2X_2$$

where, Y is intake of ME, TDN, CP or DCP, KJ or g per kg metabolic body weight ($W_{kg}^{0.75}$) per day; $X_1$ is the FCM (kg) per kg metabolic body weight; $X_2$ is the ADG (g) per kg metabolic body weight; the intercept, a, is an estimate of

**Table 1.** Mean values and variances of some of the variables analysed

| | Mean | SD | Min. | Max. | N |
|---|---|---|---|---|---|
| BW (kg) | 348.8 | 34.74 | 283 | 421 | 72 |
| FCM (kg/d) | 8.82 | 3.25 | 4.61 | 17.76 | 72 |
| ADG (g/d) | 165 | 199 | -237 | 653 | 72 |
| CPI (g/d) | 1,295 | 385 | 707 | 2,150 | 59 |
| DCPI (g/d) | 744 | 219 | 380 | 1,313 | 39 |
| DMI (kg/d) | 10.26 | 1.71 | 6.65 | 14.07 | 72 |
| MEI (MJ/d) | 96.77 | 20.68 | 62.94 | 147.81 | 71 |
| TDNI (kg/d) | 6.39 | 1.37 | 4.16 | 9.77 | 71 |
| RP | 69.02 | 10.35 | 49.90 | 70.08 | 70 |
| GP | 46.91 | 25.56 | 0 | 86 | 70 |
| Milk fat (%) | 4.41 | 0.54 | 3.30 | 6.03 | 72 |

RP, roughage % in DMI; GP, green forage % in DMI. Each observation is mean of observations on at least four animals.

maintenance requirement; the regression coefficient, $b_1$ is the estimate of requirements for production of 1 kg 4% FCM; the regression coefficient, $b_2$ is the estimate of requirements for body weight gain (g per g gain). A similar model was also used by other workers (Ratray et al., 1974; Abate, 1989; Walter and Mao, 1989; Solis et al., 1991; Paul et al., 2002; Paul et al., 2003) for estimation of nutrient requirements from feeding trial data.

### Statistical analyses

All regression analyses were performed using GLM (Generalized Linear Model) procedures (Draper and Smith, 1981; SPSS, 1996). The performance of derived prediction equations was tested by calculating predicted intake values for each data using the derived prediction model and comparing those to the actual intake values. The degree of over prediction or under prediction was expressed as mean proportional bias (%), which was calculated as the slope of the regression of the predicted values and actual values at zero intercept. A regression slope (at zero intercept) <1 indicates under prediction across the range of actual values (Rayburn and Fox, 1990; Holter et al., 1996). $R^2$ values of the unrestricted (with intercept) regression equation of actual and predicted values give an estimate of variance accounted for by the regression equation. The accuracy of prediction was analyzed using the mean square prediction error (MSPE) defined as $n^{-1}\Sigma(A-P)^2$ where, A is actual intake, P is the predicted value and n is the number of pairs of values being compared. The square root of MSPE (RMSPE) gives the mean prediction error about the mean actual intake and is normally expressed as percentage of mean actual intake. A small RMSPE indicate good prediction (Roseler et al., 1997). Additional evaluation of accuracy of prediction was done by paired t-test of actual intake and predicted values. A non-significant (p>0.05) paired t-test between observed and predicted values indicates good match between values calculated using the derived prediction model and the actual values (Wicks and Leaver, 2000).

Feeding standards were derived for nutrient requirements of different nutrients for maintenance at different body weights, for production of milk of different fat percentage and for gain in body weight.

## RESULTS

### General information about the feeding trials

The mean, SD and range of some of the variables used in the present study are presented in Table 1. The range of each variable is sufficient for realistic regression analysis and is representative of diversities observed in animal and feeding situations in India. In the database, average body weight of experimental animals ranged from 283 to 421 kg and average daily 4% fat corrected milk yield ranged from

**Table 2.** The regression equations of TDN, ME, CP and DCP requirements (mean±SE) for maintenance (a, g or KJ/kg $W^{0.75}$), milk production ($b_1$, g or KJ/kg $W^{0.75}$), and weight gain ($b_2$, g/g gain) obtained from the present database

| Nutrients | ME | TDN | CP | DCP |
|---|---|---|---|---|
| MBW, kg | 80.73±0.72 | 80.73±0.72 | 80.83±0.82 | 79.20±0.91 |
| FCM, kg | 8.78±0.39 | 8.78±0.39 | 8.54±0.45 | 8.49±0.55 |
| ADG, g $d^{-1}$ | 164±24 | 164±24 | 186±27 | 115±34 |
| Intake, g or kJ $d^{-1}$ | 96,768±2,455 | 6,396±162 | 1,295±50 | 744±35 |
| Intake per kg MBW, g or kJ $d^{-1}$ | 1,193±25 | 78.86±1.62 | 15.85±0.50 | 9.48±0.40 |
| FCM per kg MBW, g $d^{-1}$ | 0.1075±0.0041 | 0.1075±0.0041 | 0.1041±0.0042 | 0.1044±0.0055 |
| ADG per kg MBW, g $d^{-1}$ | 2.03±0.29 | 2.03±0.29 | 2.30±0.34 | 1.55±0.44 |
| No of observations [a] | 71 | 71 | 59 | 39 |
| Regression equations [b] | | | | |
| a (intercept) | 598±41 | 39.54±2.73 | 6.27±0.95 | 2.90±0.46 |
| $b_1$ (coefficient) | 5,023±348 | 332±23 | 82.29±8.15 | 57.94±3.86 |
| $b_2$ (coefficient) | 26.96±4.84 | 1.78±0.32 | 0.44±0.12 | 0.19±0.05 |
| $R^2$ | 0.77*** | 0.77*** | 0.67*** | 0.90*** |
| SE of estimate | 101 | 6.65 | 2.24 | 1.10 |

*** p<0.001; MBW, metabolic body weight ($W^{0.75}$, kg); ADG, Average daily gain in body weight.

[a] Each observation is mean of observations on at least 4 animals. [b] Model: intake/MBW=a+$b_1$ (FCM/MBW)+$b_2$(ADG/MBW).

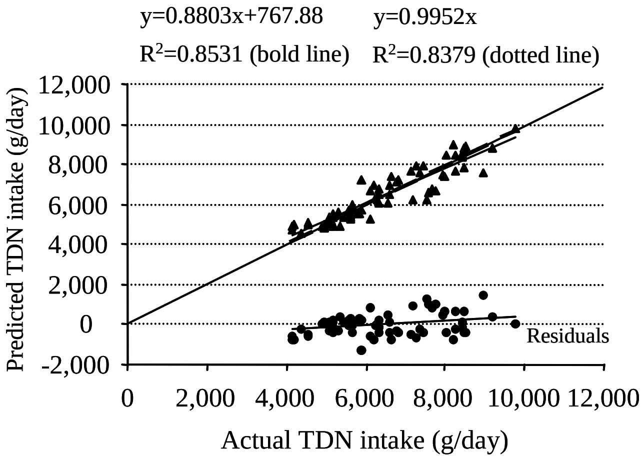


**Figure 1.** Actual vs. model predicted TDN intake. The diagonal line from origin represents y=x. The bold line represents unrestricted regression line and the dotted line represents the zero intercept regression line.

4.61 to 17.76 kg and average daily weight gain ranged from -237 to 653 g. Most of the experimental rations were roughage based (RP>50%) and roughage on an average constituted 69.02% of DMI. The mean, SE and range of milk fat percentage were 4.41±0.064 (range 3.30-6.03). Other milk constituents (e.g. protein, total solids, etc.) were not reported in most of the publications. Roughage percentage in DM ranged from 38-100% whereas green percentage in ration ranged from 0 to 86%. The mean, SE and range of TDN % and DCP % in the database were 61.83±0.61% (range 49.9 to 70.1%) and 7.49±0.26% (range 5.50 to 12.22%), respectively.

### Energy and protein requirements

The regression equations developed for the prediction of TDN, ME, CP and DCP requirements were highly significant (p<0.001) as were the coefficients and $R^2$ values (Table 2). The regression constants and partial regression coefficients give estimates of nutrient requirements for maintenance, milk production and body weight gain. Thus, the maintenance requirement of TDN was estimated to be 39.5 g/kg $W^{0.75}$ whereas TDN requirements for milk production and weight gain were 332 g/kg FCM and 1.78 g/g body weight gain, respectively. The ME requirements for maintenance, milk production and weight gain were 598 KJ/kg $W^{0.75}$, 5,023 KJ/kg FCM and 27.1 KJ/g weight gain, respectively. The prediction equation accounted for 77% of the variations in observed TDN or ME intake. Observed and predicted TDN intake values were highly correlated (r=0.92; p<0.001). The slope of the regression of the predicted values and actual values at zero intercept was very high (0.9952), which indicated very low (only 0.48% under-prediction) mean proportional bias in overall prediction. The distribution of actual and predicted TDN intake values has been depicted in Figure 1. Upon visual examination of the Figure 1 there appears to be good agreement between actual and predicted values throughout the database. The overall prediction errors (RMSPE) of TDN intake were of the order of ±521.80 g per day or

**Table 3.** Daily nutrient requirements of lactating cattle under Indian tropical condition[a]

| BW (kg) | ME (MJ) | TDN (kg) | CP (g) | DCP (g) |
|---|---|---|---|---|
| Requirements for maintenance of lactating cattle | | | | |
| 200 | 31.8 | 2.10 | 334 | 154 |
| 250 | 37.6 | 2.48 | 394 | 182 |
| 300 | 43.1 | 2.85 | 452 | 209 |
| 350 | 48.4 | 3.20 | 507 | 235 |
| 400 | 53.5 | 3.53 | 561 | 259 |
| 450 | 58.4 | 3.86 | 613 | 283 |
| 500 | 63.2 | 4.18 | 663 | 307 |
| 550 | 67.9 | 4.49 | 712 | 309 |
| 600 | 72.5 | 4.79 | 760 | 351 |
| 650 | 77.0 | 5.08 | 807 | 373 |
| 700 | 81.4 | 5.38 | 853 | 395 |
| Requirements for milk production (Nutrients required per kg of milk of different fat %) | | | | |
| 3.0 | 3.77 | 0.249 | 61.7 | 43.4 |
| 3.5 | 4.40 | 0.291 | 72.0 | 50.7 |
| 4.0 | 5.02 | 0.332 | 82.3 | 57.9 |
| 4.5 | 5.65 | 0.374 | 92.6 | 65.1 |
| 5.0 | 6.28 | 0.415 | 103 | 72.4 |
| 5.5 | 6.91 | 0.457 | 113 | 79.6 |
| 6.0 | 7.53 | 0.498 | 124 | 86.9 |
| 6.5 | 8.16 | 0.540 | 134 | 94.1 |
| Requirements for body weight gain (Nutrients required per kg gain) | | | | |
| | 27.1 | 1.78 | 440 | 190 |

[a] Calculated from regression equations for nutrient requirements obtained from the present database.

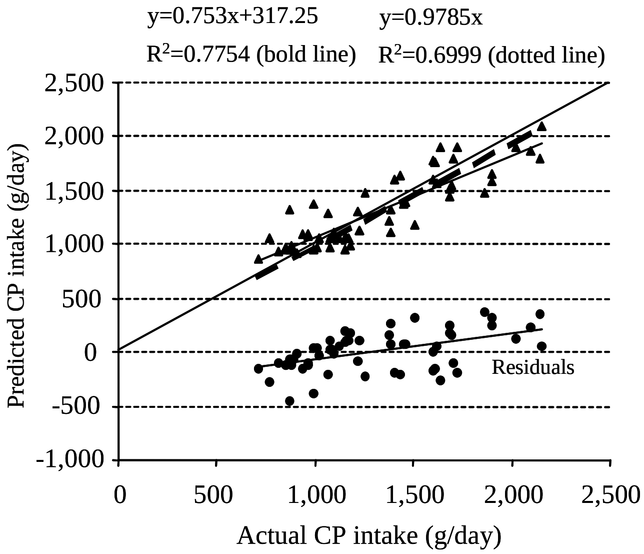


**Figure 2.** Actual vs. model predicted CP intake. The diagonal line from origin represents y=x. The bold line represents unrestricted regression line and the dotted line represents the zero intercept regression line.

approximately 8.15% of the actual intake, which indicated high accuracy of prediction across the database. A paired t-test between observed and predicted values was non-significant ($p>0.05$) which also indicated that calculated values of TDN requirements using the derived prediction models matched well with the actual intake values in this study (Wicks and Leaver, 2000). Accordingly, the standards for TDN or ME requirement were developed (Table 3).

The maintenance requirement of CP was estimated to be 6.27 g/kg $W^{0.75}$ whereas CP requirements for milk production and weight gain were 82.3 g/kg FCM and 0.44 g/g body weight gain, respectively. The prediction equation accounted for 67% of the variations in observed CP intake. Observed and predicted CP intake values were highly correlated ($r=0.88$; $p<0.001$). The distribution of actual and predicted CP intake values has been depicted in Figure 2. Upon visual examination of the Figure 2 there appears to be good agreement between actual and predicted values throughout the database. The slope of the regression of the predicted CP intake values and actual values at zero intercept was very high (0.978), which indicated very low (only 2.2% under-prediction) mean proportional bias in overall prediction. The overall prediction errors (RMSPE) of CP intake were of the order of ±181.2 g/day or approximately 13.99% of the actual intake, which indicated adequate accuracy of prediction across the database. A paired t-test between observed and predicted values was non-significant ($p>0.05$) which also indicated that calculated values of CP requirements using the derived prediction model matched well with the actual intake values in this study (Wicks and Leaver, 2000). Hence derived prediction models were utilized for development of the standards for CP requirements (Table 3).

The maintenance requirement of DCP was estimated to be 2.90 g/kg $W^{0.75}$ whereas DCP requirements for milk production and weight gain were 57.9 g/kg FCM and 0.19 g/g body weight gain, respectively. The prediction equation accounted for 90% of the variations in observed DCP intake. Observed and predicted DCP intake values were highly correlated ($r=0.95$; $p<0.001$). The slope of the regression of the predicted values and actual values at zero intercept was very high (0.9910), which indicated very low (only 0.9% under-prediction) mean proportional bias in overall prediction. The overall prediction errors (RMSPE) of DCP intake were of the order of ±68.8 g per day or approximately 9.25% of the actual intake, which indicated adequate accuracy of prediction across the database. A paired t-test between observed and predicted values was non-significant ($p>0.05$) which also indicated that calculated values of DCP requirements using the derived prediction model matched well with the actual intake values in this study (Wicks and Leaver, 2000). As the derived values matched well with actual intake values, the derived prediction models were used for developing the feeding standards (Table 3).

**Table 4.** Comparison of daily requirements from the new feeding standards with those from existing feeding standards[a]

| | Present study | ICAR (1998) | Kearl (1982) | NRC (1989) |
|---|---|---|---|---|
| Maintenance requirement, g/kg $W^{0.75}$ | | | | |
| CP, g | 6.27 | NS | 4.20 (+49) | 3.55 (+77) |
| DCP, g | 2.90 | 2.86 | 2.86 | NS |
| TDN, g | 39.5 | 33.70 (+17) | 36.50 (+8) | 35.20 (+12) |
| Requirement per kg milk of 4% fat | | | | |
| CP, g | 82.3 | NS | 79 (+4) | 90 (-9) |
| DCP, g | 57.9 | 45 (+29) | 55 (+5) | NS |
| TDN, g | 332 | 315 (+5) | 310 (+7) | 322 (+3) |
| Requirement for 1 g gain of body weight | | | | |
| CP, g | 0.44 | NS | 0.58 (-24) | 0.32 (+38) |
| DCP, g | 0.19 | 0.47 (-60) | 0.38 (-50) | NS |
| TDN, g | 1.78 | 4.43 (-60) | 2.67 (-33) | 2.26 (-21) |

[a] Values in parenthesis indicate percentage higher (+) or lower (+) in the present estimate as compared to the requirement suggested by existing feeding standards. NS: not stated in the feeding standards.

## DISCUSSION

There are wide differences between existing feeding standards for nutrient requirements for maintenance, milk production and ADG (Table 4). Some of the possible sources of variation contributing to the differences include diet quality, plane of nutrition, experimental design, method of data analysis, etc. across the experiments. Both feeding standards currently being widely used in India i.e. ICAR standard (ICAR, 1998) as well as Kearl (1982) feeding standards were based on very few data of Indian animals which may explain why these standards fail to predict nutrient requirements more accurately.

Present estimates of TDN requirement for maintenance was higher than ICAR (1998) and Kearl (1982) standards. Our estimate of maintenance requirement for ME was about 15% higher than the $ME_m$ value (521 KJ/kg MBS) predicted (calculated for a cow of 349 kg body weight using AFRC equations) by AFRC (1990) and 12% higher than the value (532.5 kJ/kg MBS) recommended by NRC (1989).

Reports on energy requirements of Indian cattle are limited. In calorimetric studies, Patle and Mudgal (1977) reported that Indian crossbred cattle requires 572.2 kJ/kg MBS for maintenance and 4,877 KJ/kg FCM for milk production during midstage of lactation whereas Patle and Mudgal (1976) reported that during early lactation Indian cattle requires 546.6 KJ/kg MBS for maintenance and 4,746 KJ for 1 kg FCM production. Our estimate for maintenance as well as milk production were slightly higher than the values reported by Patle and Mudgal (1977) and Patle and Mudgal (1976). Nutrient requirements are known to be genotype, location and dietary situation dependent. More importantly, methodological differences could be an important source of variance. Generally, estimates of nutrient requirements reported from feeding trial data using regression method are likely to be higher than the values reported from energy balance trials or calorimetric studies in any species. Optimum nutrition of producing animals calls for a higher intake than the minimum required for maintaining N or energy equilibrium in a balance trial as producing animals maintained under farm condition have more intense metabolism, expend more energy for voluntary activity and for maintaining body temperature than those of fasting animals in calorimetric chambers or those under balance trial (McDonald et al., 1995). The methodological difference in the present estimates and the values reported by Patle and Mudgal (1976, 1977) could partly explain the observed difference between the two estimates. Our estimate of ME requirement for milk production was slightly higher than the value of 4,872 KJ recommended by NRC (1989) and lower than the value of 5,222 KJ calculated using the equations of AFRC (1990). Our estimate of ME requirement for milk production was comparable (Table 4) to the value of 4,771 KJ recommended by ICAR (1998).

Our estimate of ME requirement for weight change was comparable to the values (30.85-35.52 MJ/kg ADG) reported in cattle by Siviah and Mudgal (1978). The estimate was slightly lower than the values (32.8-34.2 MJ/kg ADG) suggested by NRC (1989) and the values (36.5-45.6 MJ/kg ADG) suggested by AFRC (1990).

The DCP requirements of cattle were estimated to be 2.90 g/kg MBS for maintenance, 57.9 g/kg for FCM production and 0.19 g/g weight gain. Estimates for Indian lactating cattle as reviewed by Kearl (1982) were 2.37-4.21 g DCP/kg MBS for maintenance, 49-51 g/kg FCM production and 0.2-0.4 g DCP/g for weight gain. Our estimates of maintenance and weight gain requirements compared well with the values (2.84 g DCP/kg MBS and 0.23 g DCP/g weight gain) recommended by NRC (1989), but the estimate of milk production requirement was slightly higher than the value (51 g DCP/kg FCM) recommended by NRC (1989). Our estimate of DCP requirements for maintenance and milk production were comparable to that recommended by Kearl (1982) but the requirement for weight gain was comparatively lower than that recommended by Kearl (Table 4).

Although the amount of energy or protein required for weight gain and the amount which becomes available to the animal during weight loss are usually not the same, separate estimation for weight gain and weight loss could not be made in the present study because of the nature of the database. In the database the majority of the animals were gaining weight, and only two out of 72 groups of cattle were loosing weight. The data being insufficient for separate estimation of energy and protein requirements during weight loss, requirements for both weight gain and loss were estimated as a single component, i.e. weight change. Moreover, exclusion or inclusion of the observations on the few animals which were losing weight had no marked effect on estimates of nutrient requirements or efficiency parameters.

## IMPLICATIONS

The present study provides estimates of nutrient requirements of lactating Indian cattle reared under normal farm feeding conditions based on regression analysis of intake vs. performance values reported from different feeding trials conducted across India involving different breeds under wide dietary and climatic situations. Based on criteria of slope of regression of predicted on observed values, root mean square prediction error, correlation between observed and predicted values and paired t-test between observed and predicted values, prediction equations developed in the present study were valid and adequately accurate for predicting requirements under diverse conditions. These results suggest that the nutrient requirements derived in the present study can be used as a guide for feeding lactating Indian cattle under diverse conditions prevailing in India. Utilization of these requirements may result in the following benefits to Indian cattle industry: 1) increase in efficiency of nutrient utilization, 2) lowered feed costs and 3) optimum weight gains with lowered stress on lactating cattle. However, the requirements presented here should be updated and refined further as more feeding trial data are generated on nutrient intake and production performance under different dietary and environmental situations.

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