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Feeding standards for lactating riverine buffaloes in tropical conditions

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Summary. Data from 33 feeding trials, conducted on lactating riverine buffaloes from different institutes across India, were subjected to multiple regression analysis to derive nutritional requirements for dry matter (DM), total digestible nutrients (TDN), crude protein (CP) and digestible crude protein (DCP) for maintenance, milk production and body weight gain. Maintenance requirements for DM, TDN, CP and DCP were 59·9, 35·3, 5·43 and 3·14 g/kg$W^{0.75}$, respectively; corresponding requirements for producing 1 kg 6% FCM were 688, 406, 90·3 and 55·2 g and for 1 g gain in body weight were 3·37, 1·97, 0·327 and 0·23 g. Regression equations had high R^2 values (0·61, 0·66, 0·84 and 0·68 for prediction of DM, TDN, CP and DCP, respectively) and the equations (F-value) as well as coefficients were highly significant ($P < 0{\cdot}001$). Regressed values were used to derive feeding standards. Derived values matched well with the actual intake versus performance of animals under diverse feeding conditions. New standards predicted requirements and intake of nutrients for different production levels better than existing feeding standards. Because they are based on a more thorough analysis of data, the new feeding standards will be appropriate for use widely in India.

Keywords: Feeding standards, lactating buffalo, protein, energy, requirements.

Riverine buffaloes provide most of the milk produced in India and in many tropical countries, and are gradually replacing cattle in India. Nutrient needs of these buffaloes probably differ from those of dairy cattle of temperate countries because of differences in quality of feeds, climatic conditions and differences in efficiency of nutrient utilization. Appropriate feeding standards for buffaloes are not clearly defined, there being wide differences (as great as 40%) in nutrient requirements prescribed by various feeding standards. Most of the existing standards for buffaloes (Sen *et al*. 1978; Kearl, 1982; Pathak & Verma, 1993) are based on one, or only a few feeding trials. Because of their small, restricted database, these standards do not reflect requirements for widely different planes of nutrition, quality of feed or individual variation in animals' requirements under tropical conditions. In some feeding standards (Sen *et al*. 1978; Pathak & Verma, 1993) requirements for

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lactating buffaloes were extrapolated from studies on dry or growing buffaloes, or values were taken directly from the feeding standards for cattle of temperate countries.

Although, to date, 33 feeding trials have been conducted in India to measure nutrient intake and performance of lactating riverine buffaloes, nutrient requirements were estimated in only eight of the trials. The present study was undertaken to determine dry matter (DM) intake capacity, and energy and protein requirements of lactating riverine buffaloes using the combined nutrient intake and performance data of all of the 33 feeding trials.

MATERIALS AND METHODS

Published data from 33 feeding trials were collected. The unit of energy was total digestible nutrients (TDN) while that of protein was crude protein (CP) and digestible crude protein (DCP). Data on milk yield and fat percentage were used for calculation of 6% fat-corrected milk (FCM) yield using the formula of Rice *et al.* (1970). Only those data that contained complete information on the independent variables, milk yield, metabolic body size (kg $W^{0.75}$) and body weight changes along with any of the dependent variables (DM, CP, DCP or TDN intakes) were admitted. Equations for prediction of intake of nutrients (DM, CP, DCP and TDN) were constructed by subjecting the collected data to multiple regression analysis using the model:

$$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3$$

where Y = intake (g) of DM, CP, DCP and TDN; a = intercept or constant; b_1 = coefficient for maintenance requirement; b_2 = coefficient for 1 kg 6% FCM; b_3 = coefficient for 1 g daily gain (ADG) in body weight; X_1 = kg $W^{0.75}$, X_2 = 6% FCM (kg) and X_3 = ADG (g).

The constant 'a' represents that part of nutrient intake that is not attributable to any specific variable in the model. The a value is considered to be the sum of: the effects of environment and other variables not included in the model but which have some influence on nutrient intake; the error accrued in the determination of the variables used in the regression model; and the error due to random variation in nutrient requirements of individuals or groups of animals. However, although a is not attributable to any specific variable, partial regression coefficients for the predictor variables cannot be interpreted in a causal sense independently of the regression constant. Logically a should be zero, since when there is no need for nutrients for maintenance and production there is no nutrient intake or requirement. Hence, for calculating nutrient requirements for separate functions, a has to be distributed judiciously among the three predictor variables used in the model so that prediction error remains at a minimum while forcing the equation through a zero intercept. This was done by forcing the regression equation to pass through the origin using a model of the type used or recommended by others (Neville & McCullough, 1969; Rattray *et al.* 1974*a*, *b*; McDonald *et al.* 1995). The model has the form:

$$Y = b_1 X_1 + b_2 X_2 + b_3 X_3.$$

Comparison of the R^2 values of the two regressions indicated the loss of fit when the intercept was forced to zero. Nutrient requirements based on metabolic body size, milk yield and ADG were calculated using standardized coefficients (partial coefficients of the no-intercept model) and then compared with randomly selected

Table 1. *Prediction equations for DM, TDN, CP and DCP requirements for maintenance (b_1 g/ kg $W^{0{\cdot}75}$), milk production (b_2 g/kg 6% FCM) and body weight gain (b_3 g/g gain) derived from the present database*

Parameters	DM		TDN		CP		DCP	
$kgW^{0{\cdot}75}$	101·5		101·5		103·8		95·4	
Observations	51		51		31		33	
6% FCM, kg/d	8·92		8·92		9·06		8·16	
ADG, g	74·3		74·3		102·0		82·2	
Intake, g/d	12470		7359		1414		778	
Type of model†	U	N	U	N	U	N	U	N
a (Intercept)	2926	—	2176	—	−109·7	—	91·60	—
Coefficients ± SE								
b_1	45·5 ± 6·30**	59·9 ± 4·20**	24·6 ± 6·22**	35·3 ± 2·89**	5·95 ± 0·69**	5·43 ± 0·62**	2·76 ± 0·53**	3·14 ± 0·54**
b_2	524 ± 57**	688 ± 45**	284 ± 30**	406 ± 23**	96·4 ± 8·45**	90·3 ± 7·82**	49·6 ± 6·31**	55·2 ± 5·35**
b_3	3·37 ± 0·21**	3·37 ± 0·22**	1·97 ± 0·53**	1·97 ± 0·49**	0·33 ± 0·04**	0·33 ± 0·03**	0·22 ± 0·03**	0·23 ± 0·03**
R^2	0·65**	0·61**	0·73**	0·66**	0·85**	0·84**	0·74**	0·68**
SE of estimate	0·753	0·865	347	372	84	86	47	65

** $P < 0{\cdot}001$.

† U, Unrestricted model: $Y = a + b_1X_1 + b_2X_2 + b_3X_3$; N, No-intercept model: $Y = b_1X_1 + b_2X_2 + b_3X_3$.

experimental data, to test the accuracy of derived values. A paired t test was also performed on actual and predicted values for the whole set of data, to assess the accuracy of prediction.

Feeding standards were derived for nutrient requirements for maintenance at various body weights, for production of milk of various fat percentages and also for gain in body weight.

RESULTS

General information about the feeding trials

In all of the feeding trials, animals were fed ad lib. from a weighed allowance of feed, then daily feed intake and milk yields were recorded. In most studies, milk samples were taken weekly and analysed for solids, fat, protein and lactose. Body weights were recorded every 2 weeks. Body weight of experimental buffaloes ranged from 390 to 546 kg (mean, 472 ± 5); 6% FCM yield ranged from 4 to 16 kg (mean, $8{\cdot}9 \pm 0{\cdot}19$). Most of the experimental rations were roughage-based, and roughage on average constituted $66 \pm 1{\cdot}8$% (range, 25–92%) of DM intake and green forage constituted $44 \pm 3{\cdot}0$% (range, 0–80%) of DM intake. Mean, SE and range of DCP %, TDN % and CP digestibility were $59{\cdot}0 \pm 1{\cdot}3$% (range, 46–73%), $6{\cdot}5 \pm 0{\cdot}2$% (range, 4·9–11·7%) and $55 \pm 0{\cdot}8$% (range, 52–73%), respectively. Mean, SE and range of total solids, milk protein and milk fat in the feeding trials were $16{\cdot}3 \pm 0{\cdot}2$% (range, 13·0–18·4%), $4{\cdot}2 \pm 0{\cdot}1$% (range, 3·5–5·3%) and $6{\cdot}9 \pm 0{\cdot}1$% (range, 5·9–8·2%), respectively. The range of each variable is sufficient for reliable regression analysis and is representative of variation observed in animals and feeding situations in India. Regrettably, environmental parameters were not recorded in any of the studies. However, on the basis of the locations of the experimental stations, their climates can be adjudged to be 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.

Derived nutrient requirements

Regression equations to derive the requirements (Table 1) were highly significant ($P < 0{\cdot}01$) and had high R^2 values. Coefficients were also highly significant ($P < 0{\cdot}001$). Partitioning of the value of the constant a into b_1, b_2 and b_3 using the no-intercept model is shown in Table 1. Differences between calculated requirements and reported nutrient intakes were small and a paired t test was non-significant. Predicted requirements were incorporated into feeding standards shown in Table 2.

DISCUSSION

There is no agreement among existing feeding standards for various functions (Table 3). Possible reasons for the discrepancies include differences in age, body weight, breed, physiological state, environmental conditions, diet quality, plane of nutrition, experimental design and method of data analysis across experiments. However, the main cause of the discrepancies is the adoption of values obtained from studies with dry or non-lactating buffaloes, or taken from studies in cattle, and the use of arbitrary values for prescribing nutrient requirements of lactating buffaloes. Nutrient requirements of lactating buffaloes obtained in the present study are substantially higher than the values reported for dry buffaloes (Table 4), in keeping with many earlier studies showing maintenance requirements of lactating animals to be higher than those of dry animals (Neville & McCullough, 1969; Kurar & Mudgal, 1981).

Table 2. *Daily nutrient requirements of lactating buffaloes for various functions, derived from the prediction equations*

	DM, kg	CP, g	DCP, g	TDN, kg	ME, MJ†
	Requirements for maintenance				
Body Weight, kg					
400	5·35	485	280	3·16	47·8
450	5·85	530	307	3·45	52·2
500	6·33	574	332	3·74	56·6
550	6·80	617	357	4·01	60·7
600	7·26	658	380	4·28	64·8
650	7·70	699	404	4·55	68·8
700	8·15	739	427	4·81	72·8
	Requirement per kg milk of various fat concentrations				
Fat, %					
5·0	0·608	80·0	49·0	0·359	5·44
5·5	0·648	85·1	52·0	0·383	5·82
6·0	0·688	90·3	55·2	0·406	6·15
6·5	0·728	95·5	58·5	0·429	6·49
7·0	0·768	101	61·6	0·453	6·86
7·5	0·807	106	64·8	0·476	7·20
8·0	0·847	111	68·0	0·499	7·53
	Requirement for 1 kg gain of body weight				
	3·37	330	230	1·97	29·8

† ME values were calculated from TDN values assuming 1 kg TDN contains 15·129 MJ ME.

Table 3. *Comparison of daily requirements from the new feeding standards with those from existing feeding standards*

	Feeding standards†					
	1	2	3	4	5	6
	Maintenance requirement, g/kg $W^{0.75}$					
DM, kg	59·9	61·5	89·8	NA	77·6	NA
CP, g	5·43	NA	NA	2·81	5·23	3·44
DCP, g	3·14	2·84	2·63	1·68	3·43	NA
TDN, kg	35·3	34·3	39·9	29	38·7	35·2
	Requirement per kg milk of 6% fat					
DM, kg	0·688	NA	NA	NA	NA	NA
CP, g	90·3	NA	NA	110	108	90
DCP, g	55·2	57	68	66	76	NA
TDN, kg	0·406	0·410	0·425	0·440	0·430	0·406
	Requirement for 1 kg gain of body weight					
DM, kg	3·37	NA	NA	NA	NA	NA
CP, g	330	NA	NA	NA	NA	320
DCP, g	230	NA	NA	NA	240	NA
TDN, kg	1·97	NA	NA	NA	3·65	2·26

† 1, Present study; 2, Sen *et al.* (1978); 3, ICAR (1985); 4, Pathak & Verma (1993); 5, Kearl (1982); 6, NRC (1989).
NA = Not given in the standard.

DM requirements

None of the existing standards for buffaloes gives separate DM requirements for different functions. However, the comparison of total DM requirements (Table 3) with the existing standard revealed that the present requirements matched well with those from Sen *et al.* (1978) but were much lower than those from ICAR (1985) and Kearl (1982).

Table 4. *Comparison of daily nutrient requirements in the present study with those reported in earlier experiments with dairy riverine buffaloes*

	Maintenance, g/kg $W^{0.75}$		Milk production, g/kg 6% FCM		
Dry/lactating	Protein	TDN	Protein	TDN	Reference†
Lactating	DCP 3·20	44·5	DCP 53·0	585	1
Lactating	DCP 3·47	33·6	DCP 68·6	549	2
Lactating	—	—	—	430(320–511)	3
Lactating	—	—	—	450	4
Lactating	DCP 3·00	—	—	—	5
	CP 5·83	—	CP 102	—	
Lactating	—	49·2	—	557	6
Lactating	—	—	—	427	7
Lactating	—	—	—	376(344–400)	8
Lactating	DCP 3·14	35·3	DCP 55·2	406	Present Study
	CP 5·43	—	CP 90·3	—	
Dry	—	28·9	—	—	7
Dry	DCP 2·84	—	—	—	9
Dry	DCP 2·48	27·5	—	—	10
Dry	DCP 2·09	—	—	—	11

† 1, Mudgal & Kurar (1978); 2, Siviah & Mudgal (1978); 3, Shukla *et al.* (1972); 4, Singh *et al.* (1972); 5, Tiwari & Patle (1997); 6, Tiwari & Patle (1983); 7, Srivastava (1970); 8, Gupta (1973); 9, Gupta *et al.* (1966); 10, Kurar & Mudgal (1981); 11, Singh (1965).

Energy requirements

TDN requirement for maintenance is close to that from Siviah & Mudgal (1978) (Table 4), Kearl (1982) and ICAR (1985) (Table 3) for lactating buffaloes but much higher than the values reported for dry buffaloes (Table 4). However, the maintenance requirements for lactating buffaloes (Table 4) derived by Mudgal & Kurar (1978) and Tiwari & Patle (1983), using the regression method, were very high. Pathak & Verma (1993) based their feeding standards for lactating buffaloes (Table 3) on data from dry buffaloes (Srivastava, 1970) and growing buffaloes, and hence their values differ from the present estimates.

Protein requirements

DCP requirement for maintenance is close to reported values for lactating buffaloes but higher than those reported for dry buffaloes (Table 4). DCP requirement for maintenance is 11–19% higher (Table 3) than that from Sen *et al.* (1978) and ICAR (1985) for various body weights. Values from Pathak & Verma (1993) are very low because they were derived from non-producing animals (Table 3). CP requirement for maintenance matched well with values from Kearl (1982) but were 57% higher than NRC (1989) values for dairy cattle. This is be expected because the digestibility of CP in tropical diets (which contain poor quality fibre) is much lower than diets in temperate regions.

DCP requirements for production of 1 kg 6% FCM agree well with those from Mudgal & Kurar (1978) and Sen *et al.* (1978) (Table 4). DCP requirement from Kearl (1982) is very high in comparison, and appears to be an arbitrary value because no mention is made of the experimental basis of the estimate.

Comparative nutrient requirements of cattle and buffaloes are of interest to researchers and dairy producers. Hence, it is pertinent to compare the presently derived requirements with those estimated for Indian cattle. Estimates for Indian lactating cattle as reviewed by Ranjhan (1993), are 36·5–39·8 g TDN/kg $W^{0.75}$ per d for maintenance, 308–320 g TDN/kg 4% FCM for milk production and 2·37–4·21 g DCP/kg $W^{0.75}$ per d for maintenance. Bearing in mind the variation involved in these estimates, both biological and experimental, they appear not significantly different from the values obtained in the present study. However, the present estimate of DCP requirement for milk production (42·5 g/kg 4% FCM) is considerably lower than reported values for Indian cattle (49–51 g; Ranjhan, 1993; 55 g, Kearl, 1982). A lower DCP requirement in buffaloes may be due to the following reasons. Buffaloes have an inherent capacity to hold more NPN in their blood and to recycle it back to the rumen, which in turn increases the efficiency of utilization of absorbed protein (Ranjhan & Krishnamohan, 1977). Secondly, when compared on 4% FCM basis, buffalo milk has slightly less protein than cattle milk, which will also contribute to the lower DCP requirement. In the present database, buffalo milk has, on average, 29 g protein/kg 4% FCM. Our own review of data from 46 feeding trials on Indian cattle (S. S. Paul & A. B. Mandal, unpublished results) indicates that cattle milk contains, on average, 34 g protein/kg 4% FCM. There is little information on energy and protein requirements of lactating cattle for body weight gain but energy requirements for body weight gain (g TDN/g gain) for buffaloes in the present study are considerably lower than the value (2·67) recommended for cattle by Kearl (1982). Again, this might be expected because buffalo tissue contains less fat than that of cattle of a similar age. The lower DCP requirement for body weight gain (0·23 g DCP/g gain) in buffaloes relative to cattle (0·38; Kearl, 1982) may derive from a more efficient utilization of protein in buffaloes, as discussed above.

It is clear then that most of the existing feeding standards for lactating buffaloes either overestimate or underestimate requirements of one or more of the nutrients because they are based on very small, restricted databases; they used data from non-lactating buffaloes or cattle and they sometimes incorporated extreme estimates arising from errors in data analysis or from faulty experimentation. Since they are based on a more thorough analysis of a larger database, the new feeding standards will be appropriate for use widely in India.

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