THE COW MODEL, A MANAGEMENT TOOL FOR RUMINANT FEEDING

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SUMMARY

A model is proposed for the prediction of animal production at a given amount and quality of feed in lactating cows based partly on NRC formulae for dry matter intake (DMI) and nutrient requirements. This model was used on data gathered from farmers in the Pune district of Maharashtra, to estimate production performance from the observed availability of feeds. A wide range of nutritive values was assumed for feeds available, and varying concentrate levels were included, to predict the number of lactating cows and their production that could be supported under different options. Predicted values related well with actual field observations: predicted number of animals were 2 and 6. Predicted production was 5200 l versus 5500 in actual observations. The possible reasons for the differences include errors in (i) the data gathered, (ii) assumptions on requirements of animals, and (iii) the DMI prediction formula, especially the part dealing with the substitution rates. More information on experiments conducted with crop residues needs to be analysed to improve the accuracy of the model. The study was further intended to assess the effects of selective consumption of roughage on number of animals and their productivity. With an assumed increase of 5 units in TDN content due to selection the milk production per animal increased by 12%. The model needs to be refined but can be used to assess the effect on herd composition and individual production of innovations that are discussed elsewhere in these proceedings i.e. straw treatment as well as effects of breeding or management for straw quality and or straw quantity.

INTRODUCTION

Large variations are seen in the type and size of cattle maintained by farmers in India. Indian farmers adopt traditional methods in selection, preparation, and mixing of feeds in a wide array of feeding practices (Pradhan *et al.*, 1993). Formulation of rations for these conditions is seldom done by the extension workers/nutritionists on a short term trial and error basis but it is also necessary to advise farmer(s) on the long range planning of the (dairy) farm activities. This involves complex calculations which take into consideration a large number of variables. With the advent of computers such calculations do not pose much of a problem anymore and a need is felt to develop suitable models, so called management support models. Such models

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translate the ration formulation principles into practical guidelines as discussed in the papers during the farming systems session of this workshop (Sitaramaswamy and Jain, 1993; Vijayalakshmi *et al.*, 1993; Patil *et al.*, 1993a, b). The modeling approach needs still much refinement but can be used to help guide the research priorities and also the extension programs; although presently with low accuracy. The primary information needed for such an exercise in terms of inputs includes:

- nutrient requirements of animals for maintenance, production etc.,
- nutritive value and other characteristics of the feeds,
- availability of feeds vis-a-vis the animal performance.

The current state of knowledge on feeding standards in the tropics is still not complete (Ranjhan and Singh, 1993; Ranjhan, 1993). Differences in nutrient requirements are noted between feeding systems and differences in feeding value between species are also reported. Feeding values of commonly available tropical feedstuffs are reviewed by Prasad *et al.* (1993a, b). It may be concluded from their data that a large variation exists in the nutritive value of crop residues which form the bulk of the feeding rations in tropical countries like India. The information on voluntary dry matter intake (DMI) of the low quality roughages is inadequate and use of equations for prediction of DMI designed for conditions of so called developed countries can at best be taken as first approximations, since crop residues are hardly used as feeds in those regions (Forbes, 1988). Further these equations do not have a high predictive ability for the commonly used feedstuffs in these countries.
In view of the foregoing discussion it would be necessary to make assumptions on the basis of currently available data in order to develop a model for ruminant nutrition. This study presents an attempt in that direction. The resulting model has been applied to case studies that test the possible effects of changes in the management practices. The design and testing of such models also assist in the identification of gaps in knowledge and research priorities.

ASSUMPTIONS

Energy requirements

The requirements of energy for lactating cows are assumed to be 35 g TDN/kg$^{0.75}$ for maintenance, and 322 g TDN/kg fat corrected milk (FCM) (NRC 1988, update 1989).

Crude protein requirements

CP requirements for maintenance are assumed to be 6 g/kg$^{0.75}$ and 80 g/kg FCM. No specification was made for requirements of RDP or UDP (Walli *et al.*, 1993; Sampath, 1993).

Dry matter intake

The DMI was calculated with the following equation:

DMI = 5.4 * W / (5(100-TDNR)) + (TDNR/100) * .3FCM + (1-(1 + C/50) * (100-TDNR) / (100-TDNC)) *.5C

Where:

BW	=	bodyweight (kg)
TDNR	=	TDN content of roughage (%)
TDNC	=	TDN content of concentrates
FCM	=	fat corrected milk production (kg/day)
C	=	quantity of concentrates fed (kg/day).

The forage intake is taken to depend on forage quality and the equation 5.4 * W / 5(100-TDNR) was taken from NRC (1988). It should be noted that this equation gives reasonable predictions for low and medium quality of roughages, but because of exponentiality of the equation, the prediction for high quality roughage seems to be overestimated. The second part of the equation is included in order to account for the stimulation of intake by milk production. According to ARC (1980) each unit increase in FCM increases the DMI by 0.2 kg at an average TDN content of 65%. Hence the coëfficient for FCM was put at 0.3 per kg of TDN intake. It is known that supplementation of forages with larger quantities of concentrates will substitute forage at an increasing rate (Prasad *et al.*, 1993a). A further assumption is that substitution is essentially a function of the indigestible matter, which is expressed here with a factor (100-TDNR) / (100-TDNC). The substitution rate of indigestible matter was arbitrarily set at 0.5 based on the assumption that ground concentrate would only partly replace forage. The model predicts that SR will be higher for better as compared to lower quality roughages which agrees with ARC (1980), Ketelaars and Tolkamp (1991) and Prasad *et al.* (1993a). The increase in the SR with increased concentrates supplementation is thought to result from the pH decreasing effect resulting in reduced cell wall degradation; a situation where cell wall primarily present in forages will take up more space in the rumen. To introduce this increase in the equation the part (1 - (1 + c/50) was, also for a case study somewhat arbitrarily chosen. (This approach is based mainly on the assumption that physical factors like rumen fill determine intake. The use of alternative theories such as from Ketelaars and Tolkamp (1991) can be considered in a later stage.)

Feed availability

Information on the feed availability for the two case studies was obtained from a survey conducted in the Pune district of the state of Maharashtra. This survey involved 114 farmers of different socio-economic status. Each farmer was visited every 15 days to record the quantity of feeds offered and the animal performance (Joshi *et al.*, unpublished). The salient findings are given in Table 1.

Table 1 Feed availabilty and herd composition of farmers.

Category	Small farmer	Large farmer
Herd (units of 400 kg)		
Young	0.50	1.50
Milking	1.19	2.57
Dry	0.44	0.81
Working	0.23	1.81
Total	2.36	6.69
Feed resources, kg of DM/year		
Self grown forage	1300	16.400
Concentrate	900	2.300

THE USE OF THE MODEL FOR TWO CASE STUDIES

The proposed model made it possible to predict the DMI by the equation described earlier and to compare the predicted animal performance with the actual performance recorded through the survey. The TDN content of forage was varied from 35 to 60% with increments of 5 units. The CP content was assumed to range between 2.5 and 15% with increments of 2.5 units. The CP intake of the animals was balanced by using concentrates with a TDN content of concentrate of 65%. The concentrate supplementation was further allowed to vary from 0 to 10 kg per day per head.

The proposed model was used to suggest alternative approaches for each farmer category to improve the animal and/or the herd performance. Two approaches to increase the milk production are used, i.e. to increase the production from a given number of animals (case I), or from a given quantity of feed (case II). The first approach is more applicable to small farmers conditions since small farmers may not be in a position to reduce the number of animals. The second option is more useful for large farmers as there is a possibility to maximize the milk output by reducing the number of milking animals.

Case I: large farmer

With each of the variables indicated earlier, the expected DMI was computed. By assuming that the large farmer also will keep the non-milking stock, the number of animals that could be supported was calculated. The data of Table 2 indicate that the number of animals predicted with the model are less than the actual number of animals kept by the farmers.
Some reasons for underestimation of the number of animals could be:

- errors in the estimation of requirements of non-lactating animals, primarily due to assumed average weights, or variable requirements for maintenance or production,
- the body weight of the lactating animals was assumed to be 400 kg for calculation of nutrient requirements. The actual bodyweights of the animals maintained by the farmers may have been less resulting in lower requirements. When the bodyweight

of adult lactating cows for the estimation of nutrient requirement was assumed to be lower (350 kg versus 400 kg), the number of animals that could be supported on the farm increased to between 1.8 to 2.2 for different forage TDN contents. Because this was closer to the actual number, the further calculations were done on the basis of 350 kg animals,
- errors associated with the prediction of DMI from the proposed formula. The substitution rate predicted by the formula was lower than reported values by Prasad *et al.* (1993a),
- inaccurate estimates or measurements of feed availability and or milk production.

Table 2 Number of animals supported with available DM at different TDN values.

		Estimated no.	
Roughage TDN	Actual no.	400 kg LW	350 kg LW
60	2.57	1.7	1.8
55	2.57	1.8	2.0
50	2.57	1.8	2.1
45	2.57	1.8	2.2
40	2.57	1.7	2.2
35	2.57	1.6	2.0

On the feed with a TDN of 40-45% and available concentrate allowance of 2300 kg it would be possible to achieve a milk production of 3000-5000 kg per year/herd (Table 3). The average daily DMI recorded was 7.9 kg while the total annual production of the herd was 4830 kg which suggests that actual TDN content of forage offered was about 45%, which would be quite low.

Table 3 Effect of selective consumption on livestock numbers and the milk production of the herd and the individual animals.

	Selection 0%		Selection 25%	
TDNR	40	45	40	45
Total milk (kg/herd/year)	3087	4996	4499	5878
No. of animals	2.2	2.2	1.7	1.6
Milk (kg/an/year)	1403	2270	2646	3673

In order to predict the effects of changes in management practices on the milk production, the following alternatives were tested:
- selection of the forage by the animal,
- urea treatment of forage.

If the animals are given opportunity for selective consumption of the roughage offered they tend to eat better quality material

(Zemmelink, 1986a; Subba Rao *et al.*, 1988; Wahed *et al.*, 1990). Selective consumption is therefore a relatively easy way to improve the quality of ingested poor quality feedstuffs, provided there is excess feed. Using this approach in the case of a large farmer and assuming 25% excess feed offered with an increase in TDN of 5 units the above process was repeated to calculate the maximum number of animals that could be kept on the farm. Table 3 shows that the total annual milk production can be maintained or even increased while reducing the number of animals. The production per animal and per herd (!) could be increased by 40% by allowing selective consumption.

If urea treatment of the entire quantity of available forage results in an assumed increase in TDN content of 5 units, the level of milk production would increase to aproximately 5000 kg/year with 2.2 animals i.e. 2300 kg per animal.

It can thus be said that both the options (i.e. allowing selective consumption or treatment of forage) available to this class of farmer enables him/her to improve the productivity of the available livestock. Selective consumption does not entail additional expenses but can be adopted especially under conditions of surplus availability of forages. In practice the decision on the optimum number of animals to be kept in this regard will also be dictated by the requirement of (working) animals which are to be recruited from replacement stock as elaborated by De Wit *et al.* (1993). Thus the same production on farm can be achieved by reduction in the number of animals (through selective consumption) or from same number of animals with equal individual production (treated forage). This point is supported by Wahed *et al.* (1990) and Zemmelink (1986b).

Case II: a small farmer (SF)

The calculations were repeated for the situation of a small farmer with a fixed number of animals, the equivalent of 1.2 milking cows. In this case the required forage dry matter was computed with a variable concentrate allowance. Table 4 indicates that with a forage of 45% TDN the predicted production that could be supported was 1800 kg per year per herd. With this TDN level in the forage the DMI of forage was predicted to be 8.1 kg/animal/day. The recorded daily DMI and annual milk production were 7.5 kg and 2100 kg respectively.

The farm grown forage available with small farmers was low (1300 kg DM per farm) which indicates that large quantities have to be brought in. Such imported forage might include road side grass, grass earned as a part of wage, or purchased forage like sugarcane tops whicn are available locally during the cane harvesting season.

In this case of limited forage supply, the selective consumption by animals can not be considered to be practical but usefulness of the treatment of roughage can be assessed. Treatment of roughage can be done to reduce the cost of production or to improve the individual productivity of the animals (see session IV of this workshop). The calculated increase in DMI of roughage after treatment was in the range of 7.5-25% depending on the assumed improvement in the TDN. Thus, with treatment the quantity of (ingested) imported forage will be higher by 13-25% as compared to the untreated forage.

Table 4 Predicted requirement for forage dry matter and milk production for a small farmer with the equivalent 1.2 milking cows.

Forage TDN	Forage DM (kg/year)	Concentrate (kg/year)	Milk (kg/year)
50	2835	711	1988
45	2444	1083	1752
40	2110	1449	1697

To compensate 5 units improvement of forage with 40% initial TDN, the extra quantity of forage needed would be 300 kg which can mean an extra expenditure of INR 150-450 per year for purchase of forage alone (assuming purchase price in the range of 0.5-1.5 INR/kg DM). Further assuming treatment cost to be about INR 130 per 1000 kg, based on local estimates (exclusive of labour costs) the total additional cost would range between INR 450-850 for the year. This additional expenditure is partially offset by the lower quantity of concentrates required. This would amount to INR 900/year in this example (INR 2.5/kg concentrate). The overall savings by treatment would thus vary between INR 50-450 per year without reduction of the annual milk production. In other words, the cost of milk production in this case is reduced by INR 0.03-0.26/kg. This figure is lower than reported by Vijayalakshmi et *al.* (1988), primarily because of the difference in the assumed price of forage and production level of the cows (see session IV). It can further be seen that at these levels of production the treatment will not be economically justified when the concentrate is cheaper than INR 1.7/kg i.e. when forage DM price is larger than approximately 0.5 concentrate DM price. This low cost of concentrate is likely to occur when farmers feed homemade concentrates like rice bran which are relatively cheap.
To improve the individual production of the animals the same quantity of concentrate (as compared to use of untreated forage) is assumed to be purchased. In this case the requirements of forage DM and milk production levels are indicated in Table 5.

Feeding the same amount of concentrate but increasing the TDN content of roughage will increase milk production. As a result, the production per animal per year was calculated to improve from 1206 kg to 1752 kg by an improvement of roughage quality from 40% to 45% TDN. The production of the animals thus increased by 40%. This compares well with the productivity improvement of 55% seen earlier in case of the large farmer when urea treated forage was offered to the animals. The case of feeding similar levels of concentrate required forage and the cost of treatment would, as seen earlier, be in the range of INR 425-625 per year while the additional milk produced is seen to be approximately 500 kg which translates into INR 1500 to 2000 per year. The additional net income (produce value minus feed cost) would thus be in the range of INR 900-1600 per year.

Table 5 Forage DM required and milk production for the small farmer with similar levels of concentrates.

Forage TDN	Forage DM (kg/year)	Concentrate (kg/year)	Milk (kg/year)
50	2722	1037	2471
45	2444	1083	1752
40	2233	1130	1206

CONCLUSIONS

The proposed formula for prediction of intake and performance of animals is used to study the management options for large and small farmers. It can indicate differences resulting from changing feeding management. In the case of large farmers the possibilities to increase production by either treatment or selective consumption could be used. The choice of those farmers was to go in for smaller number of animals of higher production or larger number of animals with lower production.

In case of the small farmer, the treatment of available forage can either reduce the cost of milk production at a given level of production increase the total producton from given level of feeds. The choice would naturally be influenced by the individual resource availability and farmer's priorities. It may be concluded that the modeling approach is sound but further work will be needed to improve the accuracy of prediction of the suggested model. No account is given (yet) for a diminishing response (in terms of milk) by increasing the supply of nutrients. The response of the animal may partly be dividing nutrients to the body resources rather than to the Mammary Gland. If the substitution rate can be predicted on the basis of indigestible matter, this become an important item for further research, in terms of validation of the assumption as well as in determining of the indigestible fraction.

The model needs to be refined and validated with the results of experiments before application on a larger scale. It may be difficult to obtain adequate data to test the validity of the results of different treatments of crop residues as only limited long term experiments have been reported.

To conclude it may be said that the model as a whole is an encouraging start and is based on the available literature (e.g. substitution rates, selective consumption, treatment effects, economics of treatment). It needs to be refined where now it produces results with non-integer numbers of animals. Also, the levels of predicted production may not be correct, but the model in this stage does help to indicate patterns of animal production related with feed quality and quantity.

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