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price it fetches to the producer when we consider the realistic situation of including the cost on the maintenance of dry animals on the farms. A relevant question one may then ask is : why do the farmers indulge in milk production at all and how do they (particularly the small producers) make any additional income out of this enterprise ? Answers to these questions readily follow. As said before, the out of pocket costs involved in running this enterprise is only of the order of about 27 per cent of the total costs as the remaining 73 per cent is easily met within the existing farm resources. Again, these farmers have just one lactating animal and carry on with milk production not so much for making milk available in the market as for meeting their own family consumption requirements. And lastly, these producers may consider the costs incurred on feed items alone as most relevant and important followed to some extent by the cost on depreciation on animals. The costs on human labour (which is predominantly that of the family) may be treated by them as of minor consequence in view of the fact that this has very little opportunity cost any way. Thus, as long as the price fetched by the milk sold outside covers cost A primarily, these producers (particularly the small ones) are prepared to look upon this enterprise as a source of additional income however small this income may be.

In these circumstances, then, the question of increasing the milk supply by cultivator-producers of this region, depends on the extent to which additional resource facilities (by way of more milch animals, feed availability at low costs, easy credit terms and so on) can be procured for them, arrangements for frequent salvaging of dry animals are made as these animals at present considerably drain the farm resources, suitable and adequate methods can be evolved to procure the surplus milk from the farmers in a way convenient and profitable to them and finally proper motivation drives are launched to inculcate the farmers to look upon and treat the milk enterprise as a commercial one and to make them aware of the potentialities of this enterprise.

AN ANALYSIS OF FEED-MILK RELATIONSHIP AND COST OF PRODUCTION OF MILK ON FARMS IN THE DELHI AREA

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Even though milk plays an important role in the Indian diet and the dairy animals and bovine draft animals occupy an important position in the organisation

* This study has been carried under the guidance of Prof. J. P. Hrabovszky, Visiting Professor, Agricultural Development Council, New York, in the Division of Agricultural Economics, Indian Agricultural Research Institute, New Delhi-12. The author is thankful for his ungrudging help, guidance and constant encouragement.

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of Indian farms, very little is known about the physical and economic relationship involved in this process. Some experimental data are available on standard feeding rations and on composition of milk, but information about dairy production under actual farming conditions is limited to a few studies.[1]

Because of this lack of information, it was decided to analyse the farm business data collected by the Agricultural Economics Division of the Indian Agricultural Research Institute for 60 Delhi farms with the objective of deriving estimates of feed-milk and various costs-milk relationships. It was also hoped that this information will help in pointing out adjustment possibilities for higher milk production available to these farmers and thus in creating a better milk supply for the Delhi metropolitan area.

This analysis is based on data[2] collected by the Agricultural Economics Division of the Indian Agricultural Research Institute during the years 1960-62 by cost accounting method. Out of 19 villages in the Intensive Cultivation Block of the Institute, 8 villages were randomly selected and from each village, two holdings were selected from four different size-groups. The data related to the dairy enterprise was separated out from the farm business as a whole for this economic analysis. This paper is based on data for the year 1960-1961.

This paper has three major parts. In the first one, the efforts made in estimating a feed-milk response surface are reported and in the second part, the seasonal feeding patterns of these farmers are compared with standard feeding ration recommendations. In the third part, the cost of production for milk is analysed with regard to its components and in relation to farm size and seasonality of production.

I

Farmers keeping milch animals on their farms are confronted with the problem of deciding on the optimum feeding ration for their milch animals. To obtain maximum net income from the dairy enterprise, among others, they have to make decisions on what to feed and how much to feed. For their decisions on the combination and quantity of different feed and fodders they have to consider various limitations, because milch animals require a certain minimum combination of nutrients for body maintenance and for milk production. Though milk yields are affected by a multiplicity of causes, here we have considered only components of feed, to observe their relationship with milk yields per animal on different farms.

To be able to aggregate various feeds and thereby to facilitate working out the physical relationship between the variables, we have converted the various feeds and fodders fed into their nutritive values. The energy value of the feeds was calculated in terms of Total Digestible Nutrients (TDN). Digestible Crude Protein (DCP) was used to represent the available protein in the feed. Milk yields were taken of those animals only which were milked during the period 1960-61.

The year was divided into three seasons of four months duration each. These are: rainy, winter and summer seasons, starting from 1st of July, November and

1. V. G. Panse, V. N. Amble and T. R. Puri : Cost of Production of Milk, I.C.A.R. Report of a Survey for the Estimation of the Cost of Production of Milk in Delhi State 1953-55.

2. T. P. S. Chawdhari : Studies in the Economics of Farm Business in Kanjhawla Block, Delhi Territory 1959-60 to 1961-62 (unpublished).

March respectively. The input quantities of TDN and DCP were calculated by converting the total amounts of feeds fed during the seasons into kilograms of TDN and DCP.[3]

To have a preliminary estimate of the shape of the function to be fitted, scatter diagrams and correlation graphs were drawn. These, together with other conceptual reasons relevant to these types of relationships, advocated the fitting of a power function. An equation of the following form was fitted to each season separately :

$$Y = a\ x_1^{b_1} \cdot x_2^{b_2}$$

where Y = milk yield per season in kilograms per animal

x_1 = TDN fed per animal per season in kilograms

x_2 = DCP fed per animal per season in kilograms.

The Seasonal Equations fitted, were :

Rainy Season : $Y = 0.3639\ x_1^{1.1805**}\ x_2^{-0.0951}$	(0.1602)	(0.1291)	$R = 0.7660*$ $R^2 = 0.5874$
Winter Season : $Y = 1.632\ x_1^{0.4630*}\ x_2^{0.6832*}$	(0.1467)	(0.2133)	$R = 0.7300*$ $R^2 = 0.5329$
Summer Season : $Y = 20.42\ x_1^{0.2883}\ x_2^{0.2747}$	(0.2747)	(0.2094)	$R = 0.3270$ $R^2 = 0.1073$

** Denotes significant at 1 per cent level.

* Denotes significant at 5 per cent level.

For the rainy season function, the coefficient of multiple correlation was found to be 0.766 and significant at the 5 per cent level of significance, the coefficient of multiple determination was 0.5874, indicating that more than 58 per cent of the variation in milk production was associated with the two independent variables. While the value of t for b_1 (TDN) was 7.3689, significant at 1 per cent level of significance, the value of t for b_2 (DCP) was —0.7366, statistically not

3. The information on the nutrient content of various feeds was taken from K. C. Sen : Nutritive Values of Indian Cattle Feeds and Feeding of Animals, I.C.A.R. Bulletin Series No. 25, 1964, p. 112 onward, Appendix III.

significant. The small negative elasticity of DCP is likely to be the result of statistical error. The estimated percentage increase in milk yield associated with a unit increase in TDN fed to the animals, with DCP held constant at the geometric mean level, is 1.1805.

For the winter season the coefficient of multiple correlation was 0.7300, significant at 5 per cent level of significance. The coefficient of multiple determination indicated that 53 per cent of the variations in milk yield could be explained by changes in the independent variables. The value of t for b_1 was 3.1560 and of t for b_2 was 3.203, both significant at 5 per cent level of significance. For the summer season, the coefficient of multiple correlation was low at 0.327 and not significant. The value of t for b_1 was 1.0495 and t for b_2 1.6823 which are both not significant statistically.

The unexplained variations in milk yield may be attributed to variations in quality of feeds, differences in the productive capacity of the lactating animals, their age, size, health and breed, differences in the kind of animal (whether cow or buffalo) and finally, differences in the managerial ability of the farmers. The marginal physical products and marginal value products for the two nutrients estimated on the basis of the above three seasonal functions, are given below in Table I.

TABLE I—MARGINAL PHYSICAL PRODUCT (MPP) AND MARGINAL VALUE PRODUCT (MVP) OF TDN AND DCP AT THE GEOMETRIC MEAN LEVEL BASED ON THE SEASONAL MILK RESPONSE FUNCTIONS

Nutrients	Rainy Season		Winter Season		Summer Season	
	MPP	MVP	MPP	MVP	MPP	MVP
	Kg.	Rs.	Kg.	Rs.	Kg.	Rs.
TDN	0.9656	0.52	0.3444	0.17	0.2026	0.11
DCP	—1.0862	—0.58	6.6989	3.22	2.6997	1.59

N.B. : Milk prices used for calculating MVPs for rainy season, winter season and summer season are Rs. 20.00, 18.00 and 22.00 respectively per maund (or 54, 48 and 59 *Paise* per kg. respectively).

To be able to calculate the direction of adjustment towards an optimal level of feeding, where the marginal cost of the feed nutrients are equal to their own marginal value products, we had to estimate the average price and marginal price of TDN and DCP in the various feeds fed in the rations. For this purpose a linear function was fitted, taking TDN and DCP as independent variables and average prices of the feeds during the year as the dependent variables. Then the regression coefficients were used to calculate the marginal product, as in linear functions it equals the average product. The function fitted was $Y = 1.12 + 0.164x_1 + 0.141x_2$. The coefficient of multiple determination was 0.794, and both regression coefficients were found to be significant at the 5 per cent level of significance. Having converted per maund prices of the feed into per kilogram prices of TDN and DCP, the price of TDN was estimated at Re. 0.44 per kilogram and that of DCP at Re. 0.37.

Comparing these prices with the marginal value products from Table I, it can be seen that in the rainy season the marginal value product is Re. 0.52 while the price of a unit of TDN is Re. 0.44. This would imply that farmers could increase feeding TDN until the marginal return from milk is equal to the price of TDN, taking into consideration other incidental costs incurred.

In the case of DCP the marginal value product is negative, but because of the statistically non-significant value of the regression coefficient, no valid inferences could be made from it. Similarly, the low coefficient of multiple determination for the summer season, together with the non-significance of the regression coefficients excludes the possibility for drawing inferences based on them. However, the marginal value products for TDN and DCP fed in the winter season point to possibilities of feeding less TDN and more DCP for optimal production. Because the optimal feeding levels for the nutrients fall outside the observed range, the inference drawn here refer only to directions for adjustment, and not to recommended quantities.

Because the estimated price of DCP per kilogram at Re. 0.37 is lower than the price of TDN, this would advocate that farmers in general should feed more DCP in the winter and summer seasons, up to the capacity of the animals to digest it.

II

An alternative way of estimating the deviations from optimal feeding levels is attempted here also by comparing the seasonal feed consumption of these animals with standard feed recommendation levels.

Table II shows the seasonal variation in average level of feeding of nutrients per day per lactating animal on different size-groups of farmers. Afterwards, these are compared with the recommended[4] levels of nutrients required for maintenance and production of milk.

TABLE II—AVERAGE LEVEL OF TDN AND DCP FED PER DAY PER LACTATING ANIMAL IN DIFFERENT SIZE-GROUPS OF FARMS ACCORDING TO SEASONS

Size-groups of farms (hectares)	Nutrients Fed (in kilograms)							
	Rainy season		Winter season		Summer season		Yearly Average	
	TDN	DCP	TDN	DCP	TDN	DCP	TDN	DCP
Less than 2	6.18	0.47	5.92	0.44	5.20	0.39	5.77	0.44
2—4	5.81	0.48	7.34	0.57	6.12	0 39	6.36	0.45
4—6	5.94	0.41	7.87	0.61	6.39	0.43	6.73	0.48
6 and above	6.08	0.46	7.09	0.54	7.15	0.64	6.77	0.55
Average	5.95	0.45	7.05	0.51	6.21	0.46	6.41	0.48

4. K. C. Sen : *Op. cit.*, pp. 10-11.

Table II indicates that the largest amount of TDN and DCP were fed in the winter season. As will be evident from Table VIII this helped to produce the highest milk yield in this season. The milk yield was the lowest in the rainy season, apparently because of the low level of TDN and DCP fed. On yearly average basis, with an increase in farm size both TDN and DCP were fed in larger quantities. With the exception of the highest size-group of farms, the milk produced per lactating animal increased on similar lines.

For making comparisons with standard feed ration recommendations, we assumed that the average weight of the animals was 400 kilograms, that the average daily milk produced was 6 kg., and the average fat content of the milk was 8 per cent. These assumptions are based on the fact that about 75 per cent of the animals included in the study are buffaloes.

On the basis of these assumptions the nutrients required for maintenance as well as for production of 6 kgs. of milk per day are : 6.07 kgs. TDN and 0.688 kgs. of DCP.

Comparing the data from Table II with these recommendations, one can say that in all three seasons, on the average, DCP is fed at a considerably lower level than that recommended, while in the winter and summer seasons TDN fed, with the exception of small farmers, is well above recommendations. In the rainy season, TDN fed is slightly lower than the recommended 6.07 kgs. The overall average of TDN and DCP fed on different size-group of holdings is 6.41 and 0.477 kilograms respectively. These levels indicate a considerable gap in the DCP feeding level in comparison to the recommended 0.688 kilograms, but TDN feeding is slightly higher than the recommended ration.

In addition to the above findings there are certain other important considerations to be taken into account when selecting feeds and fodders for the ration of milch animals. Some of these are (i) availability of feeds and fodder, (ii) relative prices of nutrients in various feeds, (iii) digestibility and palatability of the feeds, and (iv) bulkiness of fodders.

III

The average cost of production per year per head of milch animal[5] and the average net income per year per milch animal are shown in Table III.

In working out the different components of cost and income, the differences between cows and buffaloes have been ignored.

From Table III it may be seen that the major component of cost is the feed which accounted for 72 per cent of total cost for these farmers, in their dairy enterprise. These feed costs were calculated at the rates prevalent in the villages. The next important is human labour cost accounting for about 11 per cent of total cost.

5. Here milch animals refer to the lactating animals as well as dry animals in the year. By this treatment the cost of maintaining the animals in their dry periods is also included. However, this may bias costs upwards as some totally non-productive animals, kept for non-economic considerations will be also included. The total number of lactating animals in the year included in the study was 61, while the number of milch animals kept was 113.

TABLE III—AVERAGE COST OF PRODUCTION OF MILK AND ITS COMPONENTS IN DIFFERENT SIZE-GROUPS OF HOLDINGS, DELHI VILLAGES

Cost Item	Size-groups of Holdings (hectares)				Overall Average	
	Less than 2	2—4	4—6	6 and above	Actual cost	Expressed as percentage of total
			(in Rupees)			
Feed	621.05	680.37	737.95	625.88	666.31	72.1
Human labour	127.92	106.43	92.23	82.72	102.32	11.1
Depreciation on milch animals	70.31	65.55	93.83	67.12	74.20	8.0
Interest on investment ..	41.34	39.88	60.32	62.12	50.91	5.5
Depreciation on capital investment	21.67	27.36	36.34	35.58	30.24	3.3
Total cost	882.29	919.59	1,020.67	873.42	923.98	100.0

Labour was charged at Re. 1 per day, the going rate in the area. Depreciation and interest on milch animals together accounted for 13.5 per cent of total costs. Interest was charged at the rate of 6 per cent per annum and the milch animals were depreciated in 8 years, starting from age 4. Depreciation on other capital investment, mainly buildings, is relatively small.

The cost incurred in rearing calves on the farms has not been included among the costs, because the value of the milk consumed is not accounted in income and feed fed to these calves approximately equals the value of the calves at the age of one year. This information is based on limited observations made in the villages where the original data were collected. The total income shown in Table IV is mainly from milk, whether consumed in the household or sold, plus the value of dung produced during the year.

TABLE IV—TOTAL COST, GROSS INCOME, NET INCOME PER MILCH ANIMAL PER YEAR AND VARIOUS MEASURES OF COST OF PRODUCTION OF MILK

1.	Gross Income	Rs.	648.15
2.	Total Cost	Rs.	923.98
3.	Net Income	Rs.	—275.83
4.	Average daily milk yield per lactating animal		5.86 Kgs.
5.	Average daily milk yield per head of milch animal		3.16 Kgs.
6.	Average daily gross income per head of milch animal	Rs.	1.78
7.	Average cost per day per head of milch animal	Rs.	2.53
8.	Average daily net income	Re.	—0.75
9.	Average cost per kilogram of milk produced	Re.	0.80

It was thought that the size of the holding will have some influence on the cost of production of milk. Table V shows the variations in average cost and return per head of milch animal in the year in the different size-groups of holdings.

TABLE V—AVERAGE TOTAL COST, TOTAL GROSS RETURNS AND NET RETURNS PER MILCH ANIMAL PER YEAR IN DIFFERENT SIZE-GROUPS OF HOLDINGS

Size-groups of holdings (hectares)	Average Total Cost	Average Gross Returns	Average Net Returns
	In Rs. per milch animal kept		
Less than 2	882.29	654.70	—227.59
2—4	919.59	613.50	—306.09
4—6	1,020.67	758.10	—262.57
6 and above	873.42	566.30	—307.12
Average	923.98	648.15	—275.83

Tables III and V indicate that total cost varies somewhat between the different size-groups. It is the 4-6 hectares group of holdings which seems to be different from the rest. The high total cost on these farms could be explained by the relatively high feed costs and the higher depreciation costs on milch animals. These two facts also help in explaining the high gross returns for the group. Total cost per milch animal is the lowest on holdings larger than 6 hectares, mainly due to lower labour and relatively low feed costs. Having a low gross returns per milch animal, however, this group has the highest net losses. The last column in the table does not indicate any trend in net returns per milch animal as holding size increases. This may be due to the fact that the percentage of milch animals kept, which are lactating, varies greatly between the groups. It was the lowest for the largest holdings at 44 per cent, and the highest at 63 per cent for holdings below 2 hectares. For holdings in the size-group 2-4 and 4-6 hectares, these percentages were 54 and 59 respectively, with the average for the groups at 54 per cent.

Seasonal variability of net income per lactating[6] animals was also calculated, as shown in Table VI.

TABLE VI—SEASONAL VARIATION IN GROSS INCOME, TOTAL COSTS AND NET INCOME PER LACTATING ANIMAL

Items	Rainy season	Winter season	Summer season	Yearly
	(in Rupees)			
Gross returns	368.57	368.51	422.41	1,159.49
Total costs	332.77	360.19	384.81	1,077.78
Net returns	35.80	8.32	37.60	81.72

6. Data in Tables VI to IX refer to lactating animals instead of milch animals kept because they aim at pointing out possibilities for shifting production between seasons.

From Table VI it may be seen that the effects of different costs and yields and prices result in relatively low return in the winter season, while returns in the summer season and rainy season are nearly equal.

The availability of various feeds was thought to be influenced by the size of farm and the seasons. To demonstrate this in Table VII, the seasonal variation in average feed cost per lactating animal in different size-groups of farms is shown.

TABLE VII—SEASONAL DIFFERENCES IN FEED COSTS PER LACTATING ANIMAL IN DIFFERENT SIZE-GROUPS OF HOLDINGS

Size-groups of holdings (hectares)	Feed Costs per Lactating Animal (in Rupees)			
	Rainy season	Winter season	Summer season	Yearly
Less than 2	199.44	197.25	240.79	637.48
2—4	207.55	252.14	264.94	724.63
4—6	236.40	274.10	297.73	808.23
6 and above	256.15	285.73	304.24	846.12
Average	224.88	252.30	276.92	754.11

The above table indicates that feed costs per lactating animal increase with the farm size in all seasons. As regards the seasonal variations, the feed costs are lowest in the rainy season and highest in the summer season. This is so because in the summer season farmers feed larger quantity of concentrates and roughages. As a result, milk yields are also higher in this season than in the rainy season, as may be seen in Table VIII.

A certain amount of seasonal variation was expected in milk production per animal. Table VIII shows the variation in the average milk yield per season per lactating animal in different size-groups of farms. It may be seen that the quantum of milk per season per lactating animal increases with increasing farm size in the rainy and winter seasons but in the summer season, it is highest for the size-group of holdings between 4-6 hectares.

TABLE VIII—VARIATIONS IN MILK YIELD PER SEASON AND PER LACTATING ANIMAL IN DIFFERENT SIZE-GROUPS OF HOLDINGS

Size-groups of holdings (hectares)	Milk Produced per Lactating Animal (in kilograms)			
	Rainy season	Winter season	Summer season	Yearly
Less than 2	616.22	649.04	627.46	1,892.72
2—4	615.93	731.43	684.71	2,032.07
4—6	737.70	799.20	794.86	2,331.76
6 and above	741.42	831.62	723.88	2,296.92
Average	677.82	752.82	707.73	2,138.37

As regards the variations in milk yields with the seasons, the winter season shows the highest milk yield and the rainy season the lowest,[7] though the differences are rather small.

Integrating the information from Tables VII and VIII, Table IX was constructed to show the seasonal variations in average feed costs incurred per lactating animal in the production of one kilogram of milk produced in different size-groups of farms.

TABLE IX—SEASONAL VARIATION OF FEED COSTS PER LACTATING ANIMAL PER KILOGRAM OF MILK PRODUCED IN DIFFERENT SIZE-GROUPS OF HOLDINGS

Size-groups of holdings (hectares)	Feed Costs per Lactating Animal per kg. Milk Produced (Rupees)			
	Rainy season	Winter season	Summer season	Yearly
Less than 2	0.32	0.30	0.38	0.333
2—4	0.34	0.34	0.39	0.357
4—6	0.32	0.34	0.37	0.343
6 and above	0.34	0.34	0.42	0.367
Average	0.33	0.33	0.39	0.350

Table IX indicates that in the summer season, the cost of feed per lactating animal per kilogram of milk produced is the highest, and in the rainy season, it is equal to that in the winter season. On all size-groups of farms, cost is highest in the summer season and is almost the same across groups with a small increase with the size of farms in the summer season.

CONCLUSIONS

It has already been observed that the feed cost accounts for the largest share of total costs, representing 72 per cent. Therefore, we could hope to lower the costs of production of milk by suggesting measures aimed at economizing on feed costs.

On the basis of the functions fitted, it may be suggested that in the rainy season more TDN and in the summer and winter seasons more DCP should be fed to milking animals. Considering the estimated price ratio of TDN to DCP, farmers could obtain higher dairy incomes if they would feed more DCP until the substitution ratio of the two nutrients equals the reverse of their price ratio thereby reaching the optimal combination of feed nutrients.

This suggestion is also supported by the comparison of the rations fed with those recommended. It was found that DCP has been fed at a lower level in all

7. Ordinarily, milk yield is highest in the winter season which is followed by the rainy and summer seasons respectively. But here milk yield in summer is higher than the rainy season, because the *kharif* fodders failed due to high rainfall in the area during the year, which resulted in poor yields of fodders. Therefore the farmers had to switch on to wheat *bhusa* which contains no DCP. Besides this, both TDN and DCP were fed less than the recommended quantities.

three seasons than the recommended quantities for maintenance and the relevant level of milk production. Therefore those feeds should be emphasised which contained higher DCP percentages to reach a balanced ration for these animals. Most of the concentrates contain higher DCP and TDN content than the roughages. Therefore it is advisable to include guar grain, *til* cake, groundnut cake and guar meal to supply balanced ration in addition to gram grain and sarson cake which have been mostly fed in the area. In the area studied, wheat *bhusa* has been fed widely to milch animals. This feed contains no DCP, thus the quantity of wheat *bhusa* should be reduced and replaced by either jowar *kadbi* or bajra *kadbi*, which are also cheaper sources of nutrients than wheat *bhusa*. Leguminous fodders are rich in protein. Farmers should, therefore, be encouraged to grow more of these with possibilities of growing berseem, gram and cow peas in *rabi* and cow peas and guar in *kharif* season in this area, which calls for a slight adjustment in the cropping pattern. However, these leguminous *rabi* crops are relatively high risk crops as they are susceptible to frost and low temperatures and to some diseases.

The analysis of seasonal net returns has suggested better possibilities in the summer and rainy seasons for expanding milk production. This is mainly a function of seasonal price differences for milk. This, however, would require a more adequate feed supply in those seasons.

On the basis of the analysis of the cost of production of milk, the major conclusion which could be drawn is that if the dairy cows and buffaloes are charged with the maintenance costs of the dry animals, then serious losses are involved in the dairy enterprise at the price levels used. The possible explanation for the persistence of dairy production under these conditions could be the willingness to produce milk when a large part of the milk produced is consumed in the household, and when the maintenance of dry cattle is governed by considerations other than economic.

ECONOMICS OF LIVESTOCK ENTERPRISE IN UTTAR PRADESH

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The livestock enterprise in U.P., as elsewhere in India, has up to the present been auxiliary to crop enterprise on almost every farm. The chief reason is that

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