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Milk production function and resource use efficiency of selected dairy breeds in the central region of Bihar

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Abstract

Dairying plays a vital role in economic development by providing income and employment opportunities to village residents. This study focuses on the central region of Bihar to assess resource use efficiency in milk production across selected dairy cattle breeds. The breeds included Graded Sahiwal, HF crossbreed, and Graded Murrah. Primary data was collected from 108 animals belonging to 70 farmers through a structured interview schedule. The resource use efficiency was estimated using the Cobb-Douglas production function, considering key inputs such as green fodder, dry fodder, concentrate, veterinary expenses, and labor expenses. The estimated parameter for green fodder was positive and statistically significant for milk production across all selected breeds: Graded Sahiwal (p<0.05), Crossbred (p<0.01), and Graded Murrah (p<0.1). The coefficients for the number of lactations were negative for all breeds, indicating that milk yield decreases with an increase in lactation numbers. The R^2 (coefficient of determination) values were 0.6523, 0.7290, and 0.4806 for Graded Sahiwal, Crossbred, and Graded Murrah, respectively, suggesting that 65.23%, 72.90%, and 48.06% of the variation in milk production was explained by the variables included in the regression model. Marginal productivity analysis indicated that increasing the use of green fodder in Graded Sahiwal, Crossbred, and Graded Murrah, as well as veterinary expenses in Graded Murrah, could enhance resource use efficiency.

Keywords: Dairying, dairy breeds, milk production, resource use efficiency, marginal productivity, lactation

1. Introduction

The dairy sector is a cornerstone of India's rural economy, significantly contributing to livelihoods, nutritional security, and agricultural sustainability. Therefore, any positive or negative shifts in this sector directly impact the economic conditions and living standards of the population. Over time, India has advanced from facing milk scarcity to becoming the world's leading producer, accounting for 24.64% of global milk production. The country's livestock population has reached 535.78 million, marking a 4.6% increase since the 2012 livestock census. The indigenous female cattle population has grown by 10%, while the exotic crossbreed cattle population saw a 29.3% rise according to the 2019 livestock census (20th livestock census). Per capita milk availability in India has risen to 459 grams per day in 2022-23 (Economic Survey, 2023-24). The profitability of milk production depends on factors such as animal productivity, the quality of green and dry fodder, veterinary services, and effective dairy animal management. Profitability also varies significantly depending on the efficiency of resources used in milk production which further depends on the utilization of the resources in different lactation (Kumar *et al*., 2022) [5]. Resource use efficiency involves optimizing the allocation of limited resources across alternatives to maximize profit (Ganesh Kumar *et al*., 2000) [1]. Water, as a crucial resource, also shows varying consumption rates across breeds (Kumar *et al*., 2023) [3]. Bihar, particularly its central region, holds substantial potential for dairy development due to its favorable agro-climatic conditions and a rich tradition of livestock rearing. However, the efficiency with which resources are utilized in dairy production, especially across different cattle breeds, is key to determining productivity and profitability. The choice of breed by different categories of farmers also depends on the availability of resources. Marginal farmers were mostly preferring indigenous breeds as per the availability of the resources and small farmers preferred crossbred animals (Kumar *et al*., 2023) [3]. Resource use efficiency in dairy farming entails the optimal application of inputs like feed, water, labor, and capital to maximize milk production. It directly impacts the economic sustainability of operations, the resilience of farming practices, and the growth of the sector. Identifying the most resource-efficient cattle breeds under local conditions is essential for enhancing productivity and guiding future breeding and management practices.

2. Methodology

The present study aimed to assess the resource use efficiency in milk production of selected dairy breeds, specifically Graded Sahiwal and HF crossbreed as cattle breeds, and Graded Murrah as a buffalo breed. The study

focused on the central region of Bihar, selecting districts like Vaishali, Patna, and parts of Muzaffarpur and Samastipur based on consultations with officials from the state's Department of Animal Husbandry. Animals from each breed were selected across different age groups to represent the entire lifespan of the breed. It was assumed that animals of varying ages in the field could, on average, depict a complete life cycle. The productive life period was categorized into three age groups: 1-3 lactations, 4-6 lactations, and ≥7 lactations, with 36 animals selected from each category. Snowball sampling was employed to identify animals in different lactation stages. Primary data was gathered from 70 farmers between January and March 2021, covering resource usage such as feed and fodder quantities and costs, veterinary expenses, miscellaneous expenses, milk yield levels, and prices. Multiple regression analysis was used to examine the relationship between milk yield and the independent variables affecting it. Both linear and Cobb-Douglas production functions were tested to determine the best model for explaining milk production. The Cobb-Douglas model was found to be the most suitable for analyzing the milk production function. The specification of the production function is as follows:

$Y_j=f(X_{1j}, X_{2j}, X_{3j}, X_{4j}, X_{5j}, N_j)$ where 'i' varíes from 1 to 5 and 'j' varies 1 to 36

- ▪ Y_j= Value of milk produced per day by jth animal (Rs.)
- ▪ X_{1j} = Value of green fodder fed per day (Rs.)
- ▪ X_{2j} = Value of dry fodder fed per day (Rs.)
- ▪ X_{3j} = Value of concentrate fed per day (Rs.)
- ▪ X_{4j} = Value of labour employed per day (Rs.)
- ▪ X_{5j} = Value of veterinary and miscellaneous expenditure per day (Rs.)
- ▪ N_j = Lactation number of the animal

The Cobb Douglas production function was specified as below:

$$\boldsymbol{Ln\ Y_j} = \boldsymbol{Ln\ b_0} + \sum_{i=1}^{5} b_i \text{ Ln } X_{ij} + \boldsymbol{b_N N_j} + \boldsymbol{\varepsilon_j}$$

Where b_0 is the efficiency parameter and b_i and b_N are the technical coefficients of respective variables. ε_j is the error term. The output (Y) and inputs (Xi) in the above production functions were measured in monetary values rather than their physical quantities because of the variabilities in quality and type of feed and fodder from one respondent to the other and can be more appreciably reflected in value terms.

2.1 Estimation of MVP and MFC from Cobb-Douglas value function

Under perfect competition, the marginal factor cost (MFC) is equal to the price of input i.e., P_{xi} and MVP is determined by multiplying the price of output (P_y) with MPP of particular input i.e., MPP_{xi} ($Py*MPP_{xi}$)

In Cobb-Douglas value function, $\frac{\partial\ Ln\ Y}{\partial\ Ln\ X_i} = \frac{\partial Y}{\partial X_i} * \frac{X_i}{Y} = b_i$; where Y = P_y*y and $X_i = P_{x_i} * x_i$ under perfect competition and 'y' and 'x_i' are the physical quantity of output and input, respectively.

$\frac{P_y \partial y}{P_{x_i} \partial x_i} * \frac{P_{x_i} * x_i}{P_y * y} = \frac{\partial y}{\partial x_i} * \frac{x_i}{y} = b_i$; showing that b_i is equal to elasticity of production in ith input.

Then, MPP = $b_i * \frac{y}{x}$ and MVP = $b_i * \frac{y}{x} * P_y$

And efficiency ratio (r) of i^{th} input = $\frac{MVP}{MFC} = \frac{b_i * \frac{y}{x} * P_y}{P_{x_i}} = \frac{b_i * y * P_y}{P_{x_i} * x_i}$

r = $b_i * \frac{Y}{X_i}$ where Y is the mean of milk yield value and X_i is the mean i^{th} input value.

In profit maximization, the resource use efficiency of an input is measured by equating MVP to MFC i.e., MVP=MFC or MVP/MFC = 1. If the ratio of MVP and MFC is considered 'r' (efficiency ratio), the value of 'r' was interpreted in the following manner:

If r >1; resource is underutilised hence, increasing its use will increase profits.

If r <1; resource is excessively or overutilised hence, decreasing the quantity of resource used, increases profits

If r=1; resource is efficiently used, that is optimum utilization of resource is there, which indicates the point of maximization.

3. Results and Discussion

The resource use efficiency of the three selected breeds was calculated by fitting in the above-mentioned production function. In order to estimate resource use efficiency, the milk production function was estimated for the selected dairy breeds using expenditure on green fodder, dry fodder, concentrate, labour expense, veterinary expense and lactation number as independent variables as mentioned in the methodology.

3.1 Input-output relationship

The input-output relationship was shown by the regression coefficient of Cobb-Douglas production function along with their standard errors are presented in the Table 1. The estimated parameter for green fodder was found to be positive and statistically significant for milk production across all the selected breeds: Graded Sahiwal (p<0.05), Crossbred (p<0.01), and Graded Murrah (p<0.1). This indicates that a 1% increase in green fodder results in a 0.47% increase in milk yield for Graded Sahiwal, 1.11% for Crossbred cows, and 1.12% for Graded Murrah. Additionally, the parameter for veterinary expenses was positive and statistically significant (p<0.05) for Graded Murrah, meaning that a 1% increase in veterinary expenditure leads to a 0.36% increase in milk yield. These findings highlight the significant role of green fodder and veterinary expenses in enhancing milk production.

Table 1: Cobb Douglas production function estimates for selected dairy breeds

Parameters	Selected breeds		
	Graded Sahiwal	Crossbred	Graded Murrah
Constant term	4.42 (0.88)	-0.36(1.54)	2.07(2.16)
Value of Green fodder	0.47** (0.17)	1.11*** (0.37)	1.12*(0.56)
Value of Dry Fodder	-0.13(0.29)	0.68(0.46)	-0.26(0.44)
Value of Concentrate	0.03(0.16)	0.22(0.29)	0.33(0.29)
Value of Labour expenses	0.0074(0.055)	-0.12(0.09)	-0.19(0.17)
Value of Veterinary expenses	-0.017(0.065)	-0.24(0.20)	0.36** (0.16)
Lactation Number	-0.03*** (0.012)	-0.03(0.04)	-0.04(0.041)
R^2	0.6523	0.7290	0.4806

Values in parentheses are (S.E.)
***significant (p<0.01), **significant (p<0.05) and, *significant (p<0.1)

As anticipated, the coefficients for lactation number were negative across all breeds, indicating that milk yield decreases as the number of lactations increases. This effect was found to be statistically significant in the case of Graded Sahiwal. The R^2 (coefficient of determination) values were 0.6523 for Graded Sahiwal, 0.7290 for Crossbred, and 0.4806 for Graded Murrah, implying that the variables included in the regression model explain 65.23%, 72.90%, and 48.06% of the total variation in milk production, respectively. Similar findings have been reported in previous studies. For example, Vishnoi *et al*. (2015) [9] found that green fodder, dry fodder, labor, and miscellaneous expenses were statistically significant for small commercial dairy farms. In medium-sized farms, green fodder, dry fodder, and miscellaneous expenses were significant, while for large farms, concentrate, labor, and miscellaneous expenses were significant. Similarly, Venkatesh and Sangeetha (2011) [8] found that green fodder, dry fodder, concentrates, and healthcare had a positive and significant impact on milk production, highlighting the potential for optimizing these inputs. The slight variations in results compared to previous studies could be attributed to differences in management practices, dairy breeds, and study locations.

3.2 Resource use efficiency

In order to estimate resource use efficiency, the marginal value of productivity (MVP) of inputs whose regression coefficients were found statistically significant in estimated production function was compared with the unit price of the respective inputs which was MFC of that input. Then, r was estimated implying that the 'r' value lesser than 1 indicated overutilization, and more than 1 indicated underutilization of a resource. As evident from Table 2, the 'r' (efficiency ratio) value was more than 1 for all resources significantly effecting milk yield. It was concluded that green fodder was underutilized in the case of Graded Sahiwal, Crossbred and Graded Murrah. The increased application of green fodder will increase the profit in the animals of all the breeds. The reason for underutilization may be the unavailability of green fodder in the study region.

Table 2: Resource use efficiency of the inputs

Breeds	Inputs	r= MVP/MFC
Graded Sahiwal	Green fodder	6.17
Crossbred	Green fodder	15.45
Graded Murrah	Green fodder	18.12
	Veterinary expense	14.62

In Graded Murrah, the efficiency ratio (r) for veterinary expenses was found to be greater than 1, indicating that these expenses are underutilized and can be increased to boost milk production. Overall, the study concluded that increasing the use of green fodder in Graded Sahiwal, Crossbred, and Graded Murrah, as well as veterinary expenses in Graded Murrah, could enhance resource use efficiency. Specifically, green fodder usage needs to be increased by 84% for Graded Sahiwal and 93% for Crossbred to achieve optimal efficiency. Similarly, veterinary expenses should be increased by approximately 94% to reach efficiency levels. Previous studies, such as Singh (2008) [7], also indicated that green fodder, dry fodder, and concentrate were underutilized, suggesting that increased feeding of green fodder and concentrate could further improve the productivity of milch buffaloes in the study area. Meena *et al*. (2012) [6] reported that concentrate was underutilized for both milking buffaloes and crossbred cows in their study. Based on these findings, it is evident that resources like green fodder and veterinary expenses need to be optimized for improved efficiency.

4. Conclusion

The functional analysis indicates that resource efficiency declines as the number of lactations increases during the productive lifespan, as reflected by the negative coefficient for lactation number. There is potential for increasing the use of green fodder across all selected dairy breeds, and veterinary expenses should be optimized throughout the productive life of Graded Murrah. The regression coefficients suggest a strong relationship between the explanatory variables and milk production. Efficient utilization of these resources could lead to increased milk production across the selected dairy breeds throughout their productive lifespan. There is a need to educate and encourage livestock rearers about scientific feeding practices for feed concentrates as well as the selection of dairy breeds as per the availability of the resources through extension programs in animal husbandry, such as demonstrations and field trips.

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