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RESEARCH ARTICLE

AN MONTE CARLO SIMULATION APPROACH FOR FUTURE STATUS OF PER CAPITA AVALAVILITY OF MILK, EGG AND MEAT IN INDIA

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ABSTRACT

An attempt has been made to analyse theper capita trends in production and per capita availability of milk, egg and meat in India from 1980-81 to 2023-24 using secondary data. The exponential functional form demonstrated the highest coefficient of determination (R^2), making it the preferred model for trend analysis. Compound Growth Rates (CGR) revealed significant growth across all three sectors, with milk production showing a CGR of 5.84 per cent in the latest decade and egg production growing at 7.23 per cent. Meat production experienced a significant and rapid increase in the initial periods. However, in recent years, the rate of growth has levelled off and is now consistently increasing at an annual growth rate of 5.01 per cent.Variability and instability indices indicated relatively low instability in production and availability, suggesting steady sectoral performance. The Monte Carlo simulation using a Logistic Growth Model forecasted future production trends from 2024 to 2028, providing insights into potential production capacities and uncertainties. Results reveal slow growth as carrying capacity is approached.

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INTRODUCTION

India now has indisputably the world's biggest dairy industryin terms of milk production; during 2023-2024, India produced close to 239.30 million tonnes of milk. The dairy sector in India has shown remarkable development in the past decade and India has now become one of the largest producers of milk and value-added milk products in the world.World milk production has grown by 1.50 per cent during 2023 (approx.) in-comparison to the year 2022 (Anon. 2024)a. India ranks first in the world in terms of total milk production (Anon.2024)c. The milk production has increased by 3.78 per centduring 2023-2024, over the estimates of 2022-2023. The / capita availably of milk is 471 grams / day. The average yield / animal / day for exotic/crossbred is 8.12kg /day/ animal and for indigenous/non-descript is 4.01kg/day/ animal. The milk production from exotic/crossbred cattle has increased by 8 per cent and indigenous/ non-descript cattle has increased by 44.76 per centin 2023-2024 as compared to previous year. The milk production from buffaloes also however decreased by 16.00 per cent as compared to previous year (Anon.2024)b. The top five milk producing States during 2023-2024 was Uttar Pradesh with a share of 16.21 per cent of total milk production followed by Rajasthan (14.51 per cent), Madhya Pradesh (8.91 per cent), Gujarat (7.65 per cent) and Maharashtra (6.71 per cent).

In terms of annual growth rate (AGR), the highest AGR recorded by West Bengal (9.76 per cent), followed by Jharkhand (9.04 per cent), Chhattisgarh (8.62 per cent) and Assam (8.53 per cent) over the previous year. India's export of dairy products was 63,738.47 MT to the world for the worth Rs2,260.94 crores/ 272.64 USD Millions during the year 2023-2024. Milk production and per capita availability from 1993-1994 to 2022-2023; indicates a strong, consistent growth in India's dairy sector. Milk production grew at an impressive annual growth rate of 4.64 per cent with high statistical significance and stability while per capita availability also showed a steady increase, growing at a CAGR of 3.12 per cent (Bey and Sharma, 2024)b. According to Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) production data (2022-2023), India ranks 2nd in Egg Production and 5th in meat production in the world. Egg production in the country has increased from 78.48 billion in 2014-2015 to 142.77 billion no. in 2023-2024. Egg production in the country is growing at the Compound Annual Growth Rate (CAGR) of 6.87per cent over the past 10 years. The per capita availability of egg is at 103 eggs / annum in 2023-2024 as against 62 eggs in 2014-2015.The major contribution in the total egg production comes from Andhra Pradesh with a share of 17.85 per cent of total Egg production, followed by Tamil Nadu (15.64 per cent), Telangana (12.88 per cent), West Bengal (11.37per cent) and Karnataka (6.63 per cent). In terms of AGR, the highest growth rate was recorded by Ladakh

(75.88 per cent) and followed by Manipur (33.84 per cent) and Uttar Pradesh (29.88 per cent). Meat production in the country has also increased from 6.69 million tonnes in 2014-2015 to 10.25 million tonnes in 2023-2024. Meat production in the country is growing at the CAGR of 4.85 per centover the past 10 years.The major contribution in the total meat production comes from West Bengal with 12.62 per cent share and followed by Uttar Pradesh (12.29 per cent), Maharashtra (11.28 per cent), Telangana (10.85 per cent) and Andhra Pradesh (10.41per cent). In terms of annual growth rate, the highest Annual Growth Rate (AGR) has recorded in Assam (17.93 per cent), followed by Uttarakhand (15.63 per cent) and Chhattisgarh (11.70 per cent), respectively. Analysingvarious methodology is beneficial for finding ways (Enders, 2014) to understand and come up with an idea to mitigate the problem wherever required in order to have a better growth rate and more accuracy to anticipate on future events. So, the question of when the production of milk, egg and meat will reach their historical maximum and be enough for the country and the world is a common concern.

MATERIALS AND METHODS

Data Base: The present study has been conducted entirely based on the secondary data. The secondary data regarding production and per capita availability of milk, egg and meat of India pertaining to the period from 1980-1981 to 2023-2024 have been acquired from the Basic Animal Husbandry Statistics, 2023 and various published sources (except for meat, the data is only of production, period *viz;* 1999-2000 to 2023-2024) for the present study.

Analytical Framework: To analyse the trend of production and per capita availability of milk, egg and meat in India, the following different functional forms were selected.

1.Linear function $Y = a + bx$
2.Quadratic function $Y = a + bc + cx^2$
3.Exponential function $Y = ab^t$

Whereas: Y = Production and per capita availability of milk, egg and meat of India

x = Time variable

The functional form having highest co-efficient of determination (R^2) is selected for fitting the trend, along with this, growth rates of production and per capita availability of milk, egg and meat of India were computed. Compound Growth Rates were also computed for production and per capita availability of milk, egg and meat based on the exponential function for the periods (Bey and Sharma, 2024). The compound growth rates were computed as follows:

The exponential function form:

$$Y = ab^t \quad (1)$$

Or ln Y=ln a + t ln b

The Compound Growth Rates (CGR) was computed by using formula:

$$CGR = \left(Antilog\ b - 1\right) \text{x } 100 \quad (2)$$

Whereas: Y= time series data on production /per capita availability of milk, egg and meat

b = regression coefficient
t= time period in years

To measure the magnitude of variability in production and per capita availability for the total period, the coefficient of variation (%) was computed. Further the instability index was also calculated to examine the instability in production and per capita availability of milk, egg and meat of India, Cuddy-Della Valle Instability Index (CDI)was calculated by using the following formula:

$$CDI = CV \times \sqrt{1 - R^2} \quad (3)$$

Whereas: CV =Coefficient of Variation
R^2= Coefficient of Determination
Also, the Monte Carlo Simulation method was also applied to predict the future milk, egg and meat production by using a Logistic Growth Model. LGM was done using the formula:

$$P(t) = \frac{K}{1+\left(\frac{K-P_0}{P_0}\right)e^{-rt}} \quad (4)$$

Whereas: P(t) =The predicted production at time t
K=The carrying capacity (saturation point),
P_0 =The initial production value
r=The growth rate.

To account for uncertainty in the growth parameters, a Monte Carlo simulation with 10,000 iterations is utilized. In each iteration, the growth rate (r) and the carrying capacity (K) are randomly sampled from normal distributions with predefined mean values and standard deviations. Specifically, the mean growth rate is set at 0.05, with a standard deviation of 0.02, while the carrying capacity is assumed to be 110 per cent of the maximum historical production value, with a standard deviation of 10 units. The initial production value, P_0, is taken as the first data point in the historical series. The Monte Carlo simulation involves generating 10,000 different sets of parameters (growth rate and carrying capacity) and applying them to the logistic growth model to simulate future production from 2024 to 2028. The predicted values for each year are collected across all simulation iterations, creating a distribution of possible outcomes.

Following the simulation, the results are analysed to provide summary statistics, including the mean, standard deviation, minimum, and maximum predicted values for each year. The outcomes are visualized through a line plot, where each line (blue) represents a single simulation run. A confidence ribbon (red) is overlaid on the plot to represent the mean confidence interval, with the shaded area indicating the uncertainty surrounding the predicted values (Dickey and Fuller, 1979; Box *et al.*, 2015).

RESULTS AND DISCUSSION

For the different functional forms *viz*; linear, quadratic and exponential coefficients of determination (R^2) were computed and are presented in the Table 1. Table 1 reveals that the R^2 values of exponential function for all two aspects *viz;* production and per capita availability of milk, egg and meat of India were higher (ranging from 0.94 to 1.00 per cent) than

Table 1. R^2 value of Linear, Quadratic & Exponential function for Milk, Egg and Meat in India

Products	Aspects	Linear	Quadratic	Exponential
Milk	Production	0.91	0.99	0.99
	/Capita Availability	0.91	0.98	0.97
Egg	Production	0.88	0.99	1.00
	/Capita Availability	0.90	0.98	0.99
Meat	Production	0.98	0.98	0.94

Table 2. Results of the fitted trend for Milk, Egg and Meat in India (Exponential function)

Products	Aspects	a	b
Milk	Production	$2*10^{-37}$	0.0445
	/Capita Availab.	$3*10^{-22}$	0.0275
Egg	Production	$3*10^{-47}$	0.0587
	/Capita Availab.	$2*10^{-35}$	0.0418
Meat	Production	$1*10^{-67}$	0.0807

Table 3. CGR (%) of Production and Per Capita Availability of Milk, Egg and Meat in India

Products	Aspects	CGR %			
		1980-81 to 1990-91	1991-92 to 2001-02	2002-23 to 2012-13	2013-14 to 2023-24
Milk	Production (Million Tonnes)	5.29*** (0.98)	4.25*** (1.00)	4.57*** (1.00)	5.84***(1.00)
	/Capita Availab. (Gram/ Day)	3.03*** (0.94)	2.26*** (1.00)	3.01*** (0.99)	4.67***(0.99)
Egg	Production (Million No)	8.08*** (0.98)	5.32*** (0.94)	6.00*** (0.99)	7.23*** (0.99)
	/Capita Availab. (No/Annum)	5.79*** (0.97)	3.22*** (0.84)	4.32*** (0.99)	6.10*** (0.99)
Meat	Production ('000 Tonnes)	1999-2000 to 2011-12		2012-2013 to 2023-24	
		10.47*** (0.87)		5.01*** (1.00)	

(Note: *** Significant at 0.1 per cent and figure in parentheses indicate value of R^2, respectively) Variation and instability in Production and Per Capita Availability

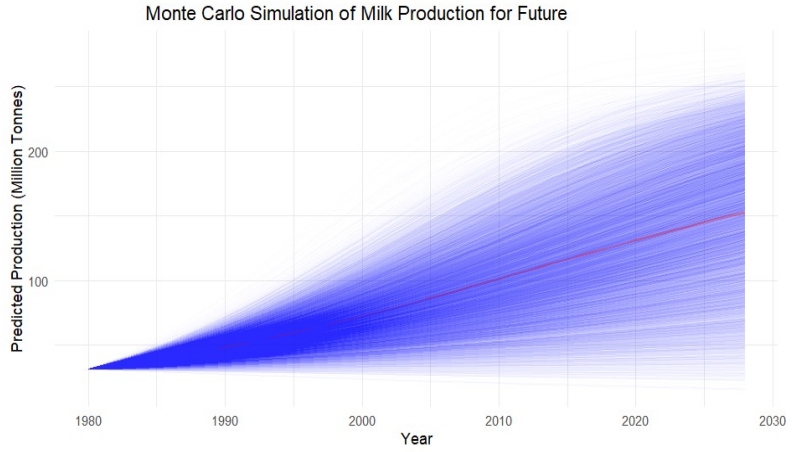

Figure 1. Future Forecast of Milk Production of India from 2024-2028

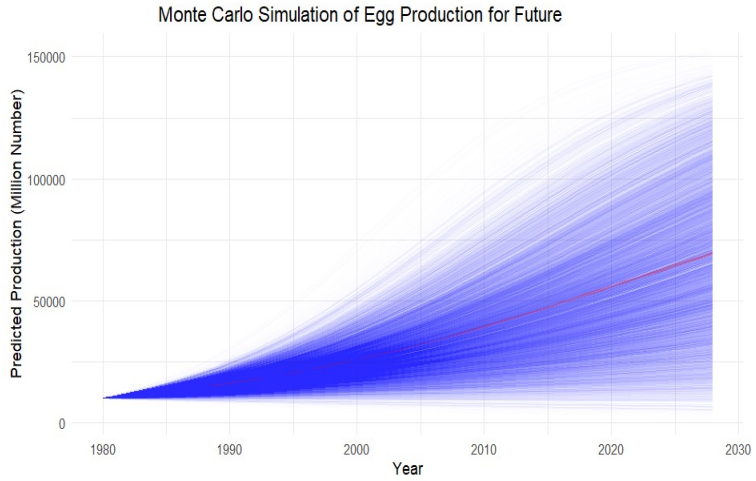

Figure 2. Future Forecast of Egg Production of India from 2024-2028

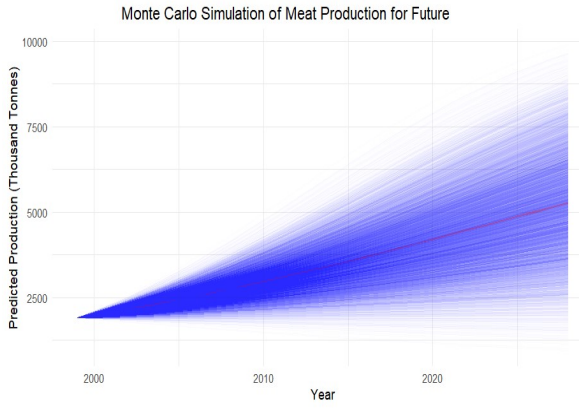

Figure 3. Future Forecast of Meat Production of India from 2024-2028

linear (0.88 to 0.98 per cent) and quadratic (0.98 to 0.99 per cent) functions except in some aspects of production and per capita availability. Hence, the exponential functional form was selected for fitting trend of production and per capita availability of milk, egg and meat based on the best fitted trend of production (Sharma, 2012). Table 2 reveals that the 'b' values in the exponential functional forms for production and per capita availability of milk, eggs, and meat are positive. This indicates promising prospects and contributions to livestock farming, particularly in these sectors. It also suggests a favourable outlook for the future, implying accelerated growth in the production and availability of milk, eggs, and meat in India (Sharma and Kalita, 2008; Sharma, 2013a; Sharma, 2015a). Table 3 reveals that the overall growth rate of milk, egg and meat was found to be positively significant at 0.1 per cent in the production and per capita availability across various time periods. Milk production demonstrated consistent growth, with the CGR increasing from 5.29 per cent during 1980-1981 to 1990-1991 to 5.84 per cent in the most recent period (2013-2014 to 2023-2024). Similarly, per capita availability of milk also showed substantial improvement, rising from 3.03 per cent in the initial decade to 4.67 per cent in the last period.Egg production experienced a robust growth trajectory, starting at 8.08 per cent during 1980-1981 to 1990-1991 and maintaining significant growth of 7.23 per cent in 2013-2014 to 2023-2024. Per capita egg availability followed a similar pattern, increasing from 5.79 per cent in the earliest decade to 6.10 per cent in the most recent period. Meat production showed remarkable growth during 1999-2000 to 2011-2012, with a CGR of 10.47 per cent. However, growth moderated to 5.01 per cent in the following period (2012-2013 to 2023-2024), indicating a stabilization in production rates (Sharma, 2013b; Sharma, 2015b; Yadav *et al.*, 2021). Table 4 reveals that the co-efficient of variation (%) of production and per capita availability of milk, egg and meat were worked out for the period 1980-1981 to 2023-2024, it shows that livestock farming *viz;* milk, egg and meat indicated high level of variation in India for the periods as revealed by the higher coefficient of variation which were more than 10 per cent except for some aspects (Sharma, 2006; Sharma,2013c; Chishi and Sharma, 2019). Table 5 reveals the instability indices which depicts that the instability indices for production and per capita availability of milk, egg and meat in India were low (ranging from 0-15) except for some aspects and thereby indicating less riskiness and maintaining stability for production and per capita availability of milk, egg and meat in India (Bey and Sharma, 2024a; Bey and Sharma, 2024b).

CONCLUSION

The above discussion highlighted the fact that the growth of production and per capita availability of milk, egg and meat of India were positive and statistically significant. The coefficient of variation indicated higher which were more than 10 per cent except for some, shows a high variation thereby indicating risky among livestock farming *viz;*milk, egg and meat. However, value of instability indices was lower and thereby indicating less riskiness and maintaining stability for production and per capita availability of milk, egg and meat in India. Further, the Predicted production trends suggest a slowing growth as carrying capacity is approached.

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