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Socio-economic impact of COVID-19 pandemic on dairy farm households in West Bengal state

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ABSTRACT

India is one of the leading economies that have been stuck hard by the COVID-19 pandemic and the stringent measures were put in place to combat it. Among several sectors, dairy sector is the most affected as dairy products are highly perishable and rely on time-sensitive supply chains. Though studies are available on the impact of COVID-19 pandemic on dairy sector, there are no studies on COVID-infected dairy farm households. The present study was an attempt to assess the socio-economic impact of COVID-19 pandemic on infected and uninfected dairy farm households in West Bengal. The study covered pre-lockdown, lockdown (both 1st and 2nd wave) and post-lockdown phases of COVID-19 pandemic. The primary data was collected from 150 dairy farm households (COVID-19 infected-75 and uninfected-75) in Murshidabad and Nadia districts of West Bengal. Dairy Economic Performance Index consisting of number of milch animals, milk yield, marketed milk, milk procurement price, concentrate price and veterinary cost was developed using principal component analysis. In order to make infected and uninfected groups statistically comparable, propensity score matching technique was employed. The index values were compared between matched infected and uninfected groups over different phases of COVID-19 pandemic. Dairy households incurred significant economic losses during the lockdown and post-lockdown periods due to increase in cost of concentrates, decline in the number of milch animals and drop in milk procurement prices. Dairy households faced constraints in procuring dry fodder, concentrate feed and in accessing veterinary care. COVID-19 infected dairy farm households had a greater socio-economic hurdle than that of uninfected households.

Keywords: Artificial insemination, Infected and uninfected households, Lockdown, Marketed milk surplus, Milk prices, Milk productivity

The livestock sector is one of the fastest-growing segments of the agricultural sector in India. It contributes nearly 29% to agricultural GDP and accounts for about 4% of the total GDP (MoF 2021). A vast majority of the rural population is dependent on livestock sector, which provides employment to around 8.8% of the total population. Moreover, dairying is a vital source of income for millions of India's rural farm households (Sarkar and Dutta 2022).

The emergence and rapid spread of COVID-19 has posed an unprecedented threat to human life across the world. Widespread health crises negatively impacted the economy through a variety of pathways, including shutdowns of production activities. Growth in the real GDP of India during 2020-21 contracted by 7.3% due to COVID-19 pandemic (NSO 2021).

Dairy farmers suffered primarily due to a dramatic decline in the demand for milk and milk products. On the supply side, dairy farmers had faced severe constraints with rise in feed and fodder costs, which increased the cost of milk production (Bhandari *et al*. 2021). A drop in milk productivity, rise in feed cost and lower milk procurement prices jointly reduced the net return of dairy farming (Alam *et al*. 2022, Thejesh *et al*. 2022).

On 24 March 2020, the Government of India declared 21-days lockdown, which had a long-term impact on Indian agriculture. Millions of farmers across the country disposed away milk into pits and canals (Barua 2021). The closure of hotels and restaurants has resulted in drop of milk sales, which had a negative impact on dairy farmers' net income. Farmers were left with excess milk because they were unable to find customers. As a result, they were bound to sell their produce at substantially cheaper prices (Das *et al*. 2021). Besides, the lack of availability of artificial insemination services during COVID-19 pandemic negatively impacted the dairy farmers' income (Bhandari and Lal 2020). The present study was aimed at assessing the socio-economic impact of COVID-19 pandemic on infected and uninfected dairy farm households in West Bengal during different phases of COVID-19 pandemic.

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MATERIALS AND METHODS

Study area and data sources: Dairying is one of the major sources of livelihood in the rural areas of West Bengal. West Bengal is placed at 12th position in milk production by contributing 5869 thousand tonnes milk in 2019-20 (MOA&FW 2022). The present study was conducted in Murshidabad (23.4710º N, 88.5565ºE) and Nadia districts (24.1659º N, 88.2625 ºE), a new alluvial agroclimatic region of West Bengal. Both the districts are dairy progressive as compared to the other districts of West Bengal, and crossbred cows shared a predominant proportion of the bovine population. The sample households were selected using multistage sampling procedure. In each district, 4 blocks were selected randomly. A total of 26 villages were selected randomly from 8 blocks of Murshidabad and Nadia districts. The infected households were selected after enquiring with local health professionals and DCS officials. A total of 150 sample households (Murshidabad uninfected-44, infected-46 and Nadia, uninfected-31, infected-29) were surveyed using detailed, well-structured and pre-tested interview schedule for eliciting the required information. The following are the time periods considered for the purpose of analysis after checking with local officials: Pre-lockdown: 1st January 2020-31st March 2020; 1st wave lockdown: 1st April 2020-31st May 2020; Before 2nd wave: 1st June 2020-31st March 2021; 2nd wave lockdown: 1st April 2021-30th June 2021; Post 2nd wave lockdown: 1st July 2021-31st December 2021.

Uninfected group: None of the family members of the dairy household being infected by COVID-19 until the survey period were considered as an uninfected group.

Infected group: If any one of the family members of the dairy farmers tested positive for corona by RT-PCR (reverse transcriptase-polymerase chain reaction) then the household was considered as COVID-19 infected. The person who is infected could have been symptomatic or asymptomatic.

Statistical analysis

Principal component analysis (PCA): The correlation analysis was undertaken to examine the linear relationship between the variables. If any two variables were highly correlated (r>0.8) then one of those two was retained. Furthermore variables were subjected to PCA and the major components were extracted. The variables which had factor loadings 0.6 and above were taken for further analysis.

Normalization of the data: Normalization of the indicators was done in order to make sure that all the indicators are comparable owing to measurement on different scales for each indicator. The following equation was employed for the normalization of indicators having positive functional relationship with their respective index.

$$\text{Normalization of data} = \frac{\text{(Actual value-Minimum value)}}{\text{(Maximum value-Minimum value)}}$$

The following equation used for normalization, if functional relationship was found to be negative.

$$\text{Normalization of data} = \frac{\text{(Minimum value-Actual value)}}{\text{(Maximum value-Minimum value)}}$$

Assignment of weight: After normalization, the weights to be assigned for each indicator were obtained from PCA and used the following equation.

$$W_i = \sum |L_{ij}| E_j$$

where, w_i, weight of the i^{th} variable; L_{ij}, loading value of the i^{th} variable on j^{th} factor; E_j, eigen value of the j^{th} factor.

Construction of the index: The calculated weights were used in the following formula to arrive at a composite index value for each significant variable.

$$Index = \frac{\sum_{i=1}^{n} X_i W_i}{\sum_{i=1}^{n} W_i}$$

where, X_i, normalized value of i^{th} variable; W_i, weight of i^{th} variable.

DEPI index value ranges from 0 to 1. Higher index value indicates better dairy economic performance and vice versa. The final composition of DEPI consisted of number of milch animals, milk yield, marketed milk, concentrate price, veterinary cost and milk procurement price.

$$\text{DEPI} = \frac{\text{(2.49*number of milch animals+2.2*milk productivity+2*marketed milk+1.43*concentrate price+1.27*veterinary cost+1.35*milk procurement price)}}{10.74}$$

Propensity Score Matching (PSM) technique: PSM technique (Rosenbaum and Rubin 1983) was employed for comparing COVID-19 uninfected and infected households of dairy farmers with respect to socio-economic impact. PSM constructs a statistical comparison group that is based on a model of the probability of participating in the infected group, using observed characteristics. Participants are then matched on the basis of the propensity score, to non-participants. The average treatment effect of the program is then calculated as the mean difference in outcomes across these two groups. The steps of the PSM estimation method are as follows:

Estimation of propensity score (PS) value: Logistic regression model was employed to calculate the conditional probability of each sample of dairy household to be infected by the COVID-19 pandemic and the value of this probability is the PS value. $P(X_i) = Pr(D_i = 1 \mid X_i)$. In this study the samples of participants, i.e. COVID-19 infected (D_i=1) and non-participants, i.e. uninfected (D_i=0) had been pooled. X_i, covariate in the PS model.

Matching of PS: The dairy households affected by COVID-19 (treatment group) were matched to each uninfected dairy households (control group) with similar PS values. This ensures that the core socio-economic characteristics of the uninfected and infected groups are as similar as possible. Samples that cannot be matched were discarded. For PSM, there are various matching approaches, but 1, 3, and 5 neighbourhood matching approach was adopted for this study.

Assessment of matching quality: The balance requirement was assessed to determine whether statistically significant

differences between two groups persist after 'resampling'. This ensured that the matching procedures balanced the data and achieve the effect of a randomized experimental design.

Calculation of average treatment effect (ATT): After matching, the impact of the COVID-19 pandemic on the infected and uninfected dairy farm households was assessed from ATT value and gap analysis.

$$ATT = E\,[Y_{1i} - Y_{0i} \mid D_i = 1] = E\,\{E\,[Y_{1i} - Y_{0i} \mid D_i = 1, p(Xi)]\} = E\,\{E\,[Y_{1i} \mid D_i = 1, p(Xi)] - E\,[Y_{0i} \mid D_i = 0, p(Xi)] \mid D_i = 1\}$$

Where, Y_{1i} and Y_{0i}, economic impact of the sample dairy farm households in the treated group and the control group, respectively.

Gap analysis: It refers to the percentage difference between the average index value in t^{th} period and that of the $(t-1)^{th}$ period.

$$\text{Index gap } (\%\ \Delta I_t) = \frac{\text{Index value during } t^{th} \text{ period} - \text{Index value during } (t-1)^{th} \text{ period}}{\text{Index value during } (t-1)^{th} \text{ period}} \times 100$$

Index gap analysis ($\%\ \Delta I_t$) was made for comparing the 2nd wave's infected dairy farm households. It was made with respect to four periods, viz. pre-lockdown period v/s lockdown of 1st wave, pre-lockdown period v/s before 2nd wave, pre-lockdown period v/s lockdown of 2nd wave and pre-lockdown period v/s post 2nd wave lockdown. The gap analysis was also used for comparing uninfected and infected households.

$$\text{Index gap } (\%\ \Delta I_e) = \frac{\text{Index value of infected group} - \text{Index value of uninfected group}}{\text{Index value of infected group}} \times 100$$

RESULTS AND DISCUSSION

Socio-economic profile: All the household heads of the sample dairy farm households were males in Murshidabad district while only 6.67% of household heads in the sample of Nadia district were females. A total of 79% farmers in Murshidabad and 73% in Nadia districts were between 41 and 60 years of age group. About 70% and 65% of farm households belonged to joint family in Murshidabad and Nadia districts, respectively. The average family size was found to be 7.16 in Murshidabad and 6.47 in Nadia district, respectively. The majority of the household heads in both the districts studied up to higher primary. Crop cultivation was the major source of income for 62 and 55% of the sample households in Murshidabad and Nadia districts, respectively. In Murshidabad district, 69 and 27% of the farmers were marginal and small farmers, respectively. Similarly, in Nadia district, 45 and 40% of the farmers were marginal and small farmers, respectively. Almost 91% of farm households in Murshidabad district and 73% of farm households of Nadia district possessed pukka house (Table 1).

The average indigenous herd size was 2.63 and 2.60 in Murshidabad and Nadia district, respectively. The indigenous in-milk animal size was 1.29 in Murshidabad district and 1.30 in Nadia district, respectively. The average crossbred herd size was 4.31 and 3.24 in Murshidabad and Nadia districts, respectively. In Murshidabad district, the crossbred in-milk animal size was 2.48 and it was 1.79 in Nadia district, respectively. In both the study districts buffalo was found in few numbers. Male adult buffalo is reared mainly for the draught purpose. The herd size of in-milk buffalo was found to be 1.53 in both districts.

Table 1. Socio-economic profile of the dairy farm households

Variable	Murshidabad no. (%)	Nadia no. (%)
Gender		
Male	90 (100)	56 (93.33)
Female	-	4 (6.67)
Age (in years)		
≤30	3 (3.33)	1 (1.67)
31-40	10 (11.14)	13 (21.68)
41-60	71 (78.87)	44 (73.33)
>60	6 (6.66)	5 (3.34)
Family type		
Nuclear	27 (30)	21 (35)
Joint	63 (70)	39 (65)
Family size		
Small (≤4)	15 (16.67)	11 (18.33)
Medium (5-7)	29 (32.22)	27 (45)
Large (>7)	46 (51.11)	22 (36.67)
Educational qualification (years)		
Illiterate (0)	7 (7.87)	5 (8.33)
Primary (1-4)	21 (23.60)	15 (25)
Higher primary (5-10)	47 (52.81)	28 (46.67)
Higher secondary (11-12)	14 (12.36)	12 (20)
College and above (>12)	2 (3.37)	-
Major source of income		
Crop cultivation	56 (62.22)	33 (55)
Dairying	16 (17.76)	10 (16.67)
Fishery	5 (5.56)	2 (3.33)
Regular salary	2 (2.22)	2 (3.33)
Business	5 (5.56)	2 (3.33)
Others	10 (11.11)	11 (18.33)
Land holding		
Landless	2 (2.22)	9 (15)
Marginal (<1 ha)	62 (68.88)	27 (45)
Small (1-2 ha)	24 (26.66)	24 (40)
Medium (2-10 ha)	2 (2.22)	-
Housing condition		
Kaccha	8 (8.99)	16 (26.67)
Pukka	81 (91.01)	44 (73.33)

Comparison of COVID-19 uninfected and infected dairy farm households during different phases of COVID-19 pandemic with respect to selected factors

Total number of milch animals: There was a significant

decline in the number of milch animals in different phases of COVID-19 pandemic both for the uninfected and infected farm households (Supplementary Fig. 1). In Murshidabad district, during the 1st wave lockdown, the mean number of milch animals decreased from 4.41 to 3.68 (P<0.01), and 5.43 to 4.69 (P<0.001) for uninfected and infected dairy households, respectively. In Nadia district, the mean number of milch animals decreased from 4.23 to 3.58 (P<0.001), and 5.07 to 3.86 (P<0.001) for uninfected and infected dairy households, respectively. The reason behind this was distress sale to meet basic family needs. Similar trend was also observed during the 2nd wave lockdown. Even during the survey, the difference in the number of milch animals for infected households continued to remain negative as compared to pre-lockdown period.

Milk productivity: In Murshidabad district, during the 1st wave lockdown, milk productivity of milch animals decreased from 6.21 to 6.15 litre/animal/day and 5.59 to 5.18 litre/animal/day by a difference of 0.05 (P>0.05) and 0.42 litre/animal/day (P<0.05) for uninfected and infected dairy households respectively as compared to pre-lockdown period (Supplementary Fig. 2). In Nadia district the reduction in milk productivity was significant during the 1st wave lockdown alone (P<0.05). The milk productivity decreased from 6.38 to 6.09 litre/animal/day and 5.45 to 5.14 litre/animal/day for uninfected and infected dairy households, respectively (P<0.05). The reason behind this was a mismatch between the supply and demand of inputs. NABARD (2020) and Bhandari and Lal (2020) also reported a dip in milk productivity during the lockdown of 1st surge of COVID-19. Before the 2nd wave, the mean milk productivity became stable for the sample dairy farm households. Lockdown of 2nd wave onwards the mean milk productivity increased for both the uninfected and infected dairy households as compared to pre-lockdown period in both the districts with the dairy input supply became stable.

Marketed milk surplus: The marketed milk surplus is more pertinent than the total milk production as it is the actual quantity made available to the non-milk producing population. The marketed milk amount depends on the milk yield and the number of milch animals. There was a significant decline in the marketed milk during the 1st wave of COVID-19 pandemic for the uninfected and infected dairy farm households in both the districts (P<0.001) (Supplementary Fig. 3). In Murshidabad district, during the lockdown of 1st wave, the marketed milk decreased from 14.69 to 9.81 litre/day (P<0.001) and 15.85 to 7.33 litre/day (P<0.001) for uninfected and infected dairy farm households, respectively as compared to pre-lockdown period. In Nadia district, during the lockdown of 1st wave the marketed milk decreased from 13.08 to 6.79 litre/day (P<0.001) and 14.83 to 5.83 litre/day (P<0.001) for uninfected and infected dairy farm households, respectively as compared to pre-lockdown period. Barua (2021) reported that milk output has decreased due to rise in cost of milk production during the COVID-19 pandemic. Further, during the post-lockdown and the 2nd wave of COVID-19 there was an increase in marketed milk in Murshidabad district as compared to the pre-lockdown period. During the 2nd wave of the COVID-19 pandemic the marketed milk declined significantly for the infected group of Nadia district as compared to the lockdown period. The possible reasons behind the decline in marketed surplus are increased family consumption; due to significant reduction in raw milk price, few households made processed milk products like ghee, paneer and chenna to minimize the losses; and drop in milk productivity which in turn led to reduction in milk production

Artificial Insemination (AI) cost: There was a significant increase in AI cost during different phases of COVID-19 pandemic both for the uninfected and infected farm households in Murshidabad and Nadia districts. In Murshidabad district, during the 1st wave lockdown the AI cost elevated from ₹130.45 to ₹155.68/shot (P<0.001) and ₹135.23 to ₹164.77/shot (P<0.001) for uninfected and infected dairy households, respectively as compared to pre-lockdown period (Supplementary Fig. 4). In Nadia district, during the 1st wave lockdown, the average AI cost increased from ₹139.81 to ₹165.65/shot (P<0.001) and ₹142.07 to ₹167.41/shot (P<0.001) for uninfected and infected dairy households, respectively as compared to pre-lockdown period. The reason behind the hike in the price of AI was irregular supply and unavailability of frozen semen. As a result, many animals missed AI when they were going through heat. Bhandari and Lal (2021) reported that due to missed AI during the lockdown, dairy farmers may have faced a direct loss of ₹989 crores. Similar trend was also observed during the post-lockdown phases and 2nd wave lockdown. There was stability in the cost of AI on the date of this survey but still the difference in the mean AI cost for infected households continued to be more as compared to pre-lockdown period. During the 1st wave lockdown, the cost of AI incurred by the infected group was more than uninfected group as para-veterinarians were reluctant to visit infected households.

Milk procurement price: The procurement price of milk is an important parameter to determine the economic impact of COVID-19 pandemic on dairy farm households. Fear of COVID-19 made consumers hesitant to buy milk directly from dairy farm households. As a result, farmers supplying milk to these households were forced to reduce milk prices to prevent wastage. During the 1st wave lockdown, the milk price dropped by ₹3.93/litre (₹32.75 to ₹28.82/litre) and ₹4.56/litre (₹31.78 to ₹27.22/litre) for the uninfected and infected farm households, respectively in Murshidabad district (P<0.001) (Supplementary Fig. 5). Milk procurement price was less for infected households as the infected members had more difficulty to reach DCS, and milk vendors stopped to collect milk from them. So, some infected dairy households distributed milk to neighbours at a nominal rate or at free of cost. In Nadia district, the milk price was lowered by ₹3.48/litre (₹30.28 to ₹26.79/litre) and ₹4.26/litre (₹30.48 to ₹27.33/litre) for the uninfected

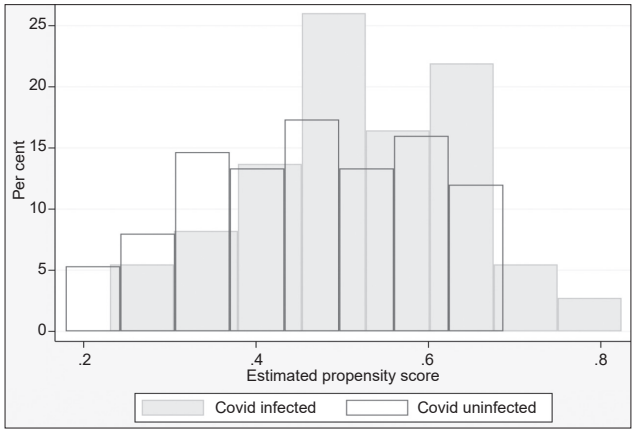

Fig. 1. Common support showing the frequency distribution of propensity score of infected and uninfected dairy households.

and infected farm households, respectively (P<0.001). The dairy households of Murshidabad and Nadia districts were selling milk at around ₹32 to ₹34/litre (Shende *et al.* 2020, NABARD 2020, Kakati *et al.* 2021).

Dairy Economic Performance Index (DEPI) of dairy farm households to assess the impact of COVID-19 pandemic: Fig. 1 depicts the frequency distribution of propensity scores for infected farm households superimposed on that of uninfected farm households. It is evident that except at tails, there is substantial overlap in the distribution ensuring common support condition is met. This indicates that the infected and the uninfected control groups are comparable.

Table 2 reports the overall estimates of the ATT and gap analysis (% ΔI_g) of infected and uninfected households in both Murshidabad and Nadia districts. During the 1st wave lockdown, the overall DEPI index value had declined by 6.25 to 6.77% for the infected group as compared to the uninfected group (P<0.01). During the 2nd wave lockdown, the gap in DEPI between the uninfected and the infected household was 1.28 to 2.96% in the study area.

Gap analysis of DEPI for the 2nd wave's infected dairy farm households: Out of 150 sample households from West Bengal, a total of 13 household members got infected during the 2nd wave of COVID-19 pandemic, of which 7 were from Murshidabad and 5 from Nadia

Table 2. Average difference and gap analysis of overall DEPI (% ΔI_g) after propensity score matching of infected and uninfected dairy households

Number of match	1st wave lockdown	% ΔI_g	Before 2nd wave	% ΔI_g	2nd wave lockdown	% ΔI_g
m=1	-0.0352**	-6.77	0.0002	0.04	-0.0137	-2.96
	(0.0173)		(0.0165)		(0.0148)	
m=3	-0.0325**	-6.25	0.0015	0.35	-0.0059	-1.28
	(0.0141)		(0.0143)		(0.0142)	
m=5	-0.0340**	-6.55	0.0012	0.28	-0.0082	-1.78
	(0.0143)		(0.0146)		(0.0148)	
Observation	148					

Significant at ** P<0.01. Standard errors are in parentheses.

Table 3. Gap analysis of DEPI (% ΔI_t) for the 2nd wave's infected dairy farm households during different phases of the COVID-19 pandemic

District	% ΔI_t (with respect to pre-lockdown period)			
	Lockdown of 1st wave	Before 2nd wave	Lockdown of 2nd wave	Post 2nd wave lockdown
Murshidabad (N=7)	-3.55*	-13.02*	-30.29**	-13.03
Nadia (N=5)	-9.22*	-13.67*	-21.75**	-12.19

Significant at *P<0.05; **P<0.01.

district. Although they encountered the usual problem initially, by the 2nd wave, the challenges had multiplied. In Murshidabad district, the DEPI index value for the infected group dropped significantly by 30.29% for the lockdown of the 2nd wave compared to the pre-lockdown period while the reduction was 21.75% for Nadia district (Table 3).

Death cases due to COVID-19: The bereaved families of COVID-19 victims were among the most vulnerable social groups in the COVID-19 pandemic. During the survey, two farm households had reported deaths due to COVID-19 during the 1st wave of COVID-19. Among the two expired farmers, one was from Murshidabad and another one from Nadia district. The deceased farmer's family members from the Murshidabad district faced severe constraints in their day-to-day life and economic activities. The members of the family were affected by various psychological crises (deep sense of loss and emotional shock, etc.). They sold 2 animals from herd size of three and the remaining one was managed by the farm women. The family members were totally isolated from others for about 10 days after the death and the animal was fed with stocked dry fodder and concentrates. The milk after household consumption was wasted since they could not sell it. The respondents stated that a few relatives and friends came forward to help them directly and indirectly. In Nadia district, the deceased family member was the household head and the only earning person in the family. The family was affected miserably. They sold their milch animals to meet their basic needs and to pay off an imminent debt. During this period the government extended support to the family by providing cash and kind assistance.

The procurement price of milk was declining coupled with increase in feed prices during the pandemic which led to significant income loss to the dairy farmers. Hence, the government should ensure providing more incentives in the form cash to compensate the loss, especially during the pandemic or such other crisis. During the 1st wave lockdown, DEPI value was lesser by 7% for the infected group than that of uninfected group, and DEPI among the infected dairy households during 2nd wave was declined up to 30% compared to pre-lockdown period. As infected dairy farmers incurred more losses during COVID-19 pandemic, the additional cash and kind support may be extended to them.

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