

Article



# Impacts of COVID-19 on Small-Scale Dairy Enterprises in an Indian Megacity—Insights from Greater Bengaluru

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**Abstract:** Natural calamities and pandemics massively affect small-scale entrepreneurs. In this paper, we aim to assess how the COVID-19 pandemic affected small dairy farms in the megacity of Bengaluru, India, where they supply a high share of the milk demand. In 2020 a total of 129 farms were visited before the first lockdown (January to March) and interviewed again after the lockdown had been loosened (August to September). Questions addressed feed supply to dairy cows, milk yield and marketing, and coping strategies for lockdown impacts. Results showed that the share of farmers not feeding concentrates increased from 1% before lockdown to 7% afterward (p < 0.05), and those not offering dry forages increased from 20% to 33% (p < 0.05) due to increasing forage prices. Milk yield dropped in all surveyed farms from 3905 L before to 2861 L after lockdown (p < 0.05) due to the sale of 30% of lactating cows across the farms. Enabling farmers to better cope with shocks through feed storage and by processing their surplus milk into durable products should be prioritised by supporting institutions such as dairy cooperatives. Alternatively, insurance schemes can capacitate farmers to maintain a fresh milk supply to urban consumers in the wake of global challenges.



# 1. Introduction

Urbanization is a major trend of the 21st century; in the next decade, this phenomenon will be strongest in Asia and West Africa, creating both opportunities and challenges [1]. On the one hand, people move into urban areas to achieve a better quality of life [2]. On the other, this puts enormous pressure on land, food production, and other natural resources in cities and their outlying neighbourhoods [3,4]. The extensive use of land for buildings, roads, and other infrastructure leaves little space for food production near cities, threatening the food security of the urban population [4,5]. Cities mostly depend on rural food production systems, but in the Global South, part of the food has to be produced in and around cities to fulfill the demand of city dwellers because of weaknesses in the food value chain, such as weak cool-chains [3,5]. Food production in both rural and urban areas can be threatened by natural calamities (e.g., floods, droughts, earthquakes, tsunamis, firestorms) as well asdiseases (epidemics and pandemics; [6]). Wheeler and Braun [7] estimated that by 2050, global food production could decline by 8% due to natural calamities. Historically, pandemics like the Spanish flu (1918, [8,9]); Ebola (2013–2016, [10]); the Hong Kong flu (1968, [9]); SARS (2002–2003, [11]); and avian influenza (1997, 2005, 2009–2010, 2014, [9,11]), had far-reaching economic, social, and political consequences [12]. In 2019, the advent of the novel SARS-CoV-2 virus evolved into one of the most serious pandemics of the past 100 years [13]. The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2, colloquially known as COVID-19) was first diagnosed in Wuhan, China, in December 2019 [14]. From China, this highly contagious disease spread around the globe in a couple of months, becoming pandemic by March 2020 [15]. In many countries, a lockdown was



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**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). imposed on the population to slow the spread of infection, strongly affecting all aspects of public and private life, industries, and the economy [13,16]. Pandemics also have direct and indirect effects on food production and supply chains [8] because of the strong dependency of the latter on (long-distance) transportation and the perishable nature of many food items such as milk. In consequence of the COVID-19 lockdowns, milk was dumped in the United States of America [17], Canada [18], India [19], and the United Kingdom [20], while spoilage of high quantities of milk was reported from eastern Africa [21]. In addition, a reduced demand for milk and falling milk prices were observed in Brazil [22], the United States of America [22], Bangladesh [23], Iran [24], and India [13], leading to further challenges for dairy producers.

Before the outbreak of COVID-19, the livestock sector contributed 5.1% to India's GDP (2018–2019, [25]), providing primary income opportunities for 70 million people [26]. India produces 188 million tons of milk in a year-20% of the global milk production-with a 6% annual growth rate [26]. In India, the first strict COVID-19 lockdown started on 24 March 2020 and was prolonged several times until 31 May 2020. From 1 June 2020 onward, a partial lockdown was introduced, allowing essential services, industries, and farms to resume their activities [19,27,28]. However, the pandemic led to a 4.8% decrease in the Indian economy in 2020 and is projected to cause a further 2.8% economic loss in 2021 [29,30]. According to Chandel et al. [28], the Indian dairy sector lost approximately 9 million US dollars every day during the lockdown due to a 25–30% reduction in the demand for milk, increased milk production costs, and a falling milk price [13,19]. The effects of the COVID-19 crisis on the dairy sector, which resulted in milk dumping by protesting farmers, were covered by several Indian newspapers, online portals, blogs, and television broadcasts [19,31,32]. Immediately after the start of the lockdown, two scientific reports discussed the problems of a reduced consumer demand for milk, falling milk prices, and unavailability of industrial dairy feed [27,33]. Kumar et al. [13] pointed to the worsening cost-benefit ratio of dairy farming in Uttar Pradesh State. Meanwhile, Uddin et al. [23] highlighted differences in the economic loss of dairy farms according to herd size. Yet, all of these studies discussed the consequences of the lockdown rather than the strategies dairy producers used to cope with its consequences, focusing on rural dairy production systems. However, a substantial amount of milk is also produced by small-scale farmers in and around the towns, cities, and megacities of India, such as in Bengaluru, Southern India [34]. Bengaluru hosts a very active and diversified dairy production sector that mainly builds on smallholder farmers keeping two to five lactating cows [35]. Dairy producers in and around Bengaluru supply their cows with finger millet straw, Napier grass, African tall maize, wild grass, and commercial concentrate feeds. Pinto et al. [36] reported an average milk yield of 10.7 L per animal and day on dairy farms in and around Bengaluru. Dairy producers rely on dairy cooperatives for inputs, e.g., veterinary care and concentrate feeds, collection of their milk, and transport to a processing plant. In addition, milk is sold directly to neighbours or restaurants through middlemen [35]. Given these differences, we hypothesized that Bengaluru's dairy farmers were affected by the lockdown. We particularly aimed to understand which mitigation strategies they adopted to deal with the impacts of the COVID-19 lockdown and if the size of the dairy herd affected their choice of mitigation strategy.

#### 2. Materials and Methods

#### 2.1. Study Area, Dairy Farmers, and Surveys

The survey was conducted in the Greater Bengaluru region (Figure 1); Bengaluru is the capital city of the southern Indian state of Karnataka, and the city presently hosts about 10 million inhabitants [37]. Located on the Decca plateau, at 600 to 900 m above sea level (m a.s.l.) in the southern half and 300 to 600 m a.s.l. in the north, ambient temperatures at Bengaluru average 26 °C across the year and yearly rainfall amounted to 1146 mm in the period 1989–2018 [38,39]. Across the city's urban, peri-urban, and rural areas, dairy farming is present and contributes to the income of the involved families [40]. The current



number of approximately 137,000 dairy cows in the Greater Bengaluru region yield about 295,000 L of milk per year [41].

Figure 1. India (left), and the Greater Bengaluru region (right) hosting the 129 surveyed dairy farms.

We originally selected 18 lakes, where we found cattle grazing or dairy farmers harvesting fodder for their cows to study the utilisation of cattle fodder from public grounds such as lakeshores. Owners of grazing cattle were found through scouting the lake surroundings and the snowball sampling method, and 98 dairy farmers grazing their cattle or harvesting cattle feed near one of the numerous lakes of Greater Bengaluru were selected. In addition, 47 dairy farmers who did not rely on forages from lake shores were randomly selected from a previous survey [36] to act as the control group. In total, 145 dairy farmers keeping at least two lactating (L) or dry (D) cows or already inseminated heifers (H) to guarantee a market-oriented production were asked for their oral agreement to conduct an interview and agreed. The survey participants were visited for a direct interview at their farm between 18 January and 20 March 2020 (before lockdown). The location of each farm was georeferenced with a handheld GPS device (Garmin eTrex 10, Schaffhausen, Switzerland), and a face-to-face interview was conducted with each farmer based on a structured questionnaire with open and closed questions. Just after our first interview round, a strict COVID-19 lockdown started on 24 March 2020 and was prolonged several times until 31 May 2020: vehicle movements between states and districts were completely restricted except for emergencies [42]. The government supported work from home as far as possible. All public and private organizations, hotels, restaurants, markets, and most shops closed. Only shops selling food items, milk booths, and animal fodder stores were allowed to open from 6 to 10 am [42]. Afterward, a partial lockdown was introduced from 1 June 2020 onward (Figure 2). To understand the impacts of the COVID-19 lockdown on the surveyed dairy farmers, we conducted a follow-up interview by telephone from 22 August to 12 September 2020 (after lockdown). Out of the 145 dairy farmers, 16 could not be reached again. Both interviews before and after lockdown explored aspects of cattle feed availability, feed acquisition and feeding management, milk production and milk marketing, as well as access to dairy farming inputs and services and long-term farm management plans (Appendix A). In the telephone interview, the questions were rephrased



in such a way that the effects of the COVID-19 lockdown on the different aspects could be captured.

Figure 2. Phases of COVID-19 lockdown in India, 2020.

#### 2.2. Data Analysis

The average number of LDH was 4.5 per farm. Based on LDH numbers, we defined threshold values for farm size as follows: the first quartile range depicts small farms (2–3 LDH; n surveyed dairy farms = 52), the second and third quartile ranges depict medium farms (4–6 LDH; n = 55) and the fourth quartile range depicts large farms (7–10 LDH; n = 23; Table 1).

**Table 1.** Number (n), herd size, and milk yield of surveyed dairy farms per size category in Greater Bengaluru, India.

Farm Size	n	Lactating, Dry Cows and Heifers (n)			Milk Yield (L/d)		
		Total	Mean	SD	Total	Mean	SD
Small	52	138	2.7	0.5	381	7.3	3.9
Medium	54	252	4.8	0.8	491	9.1	3.3
Large	23	184	8.0	1.1	186	8.1	2.7

SD: Standard deviation.

Data were analysed (n = 129) using tabulation software and open-source statistical software R (version 4.0.3). Descriptive statistics concerning different farm sizes and the time period before the lockdown and after lockdown establishment (independent variables) were computed by calculating frequencies and percentages for categorical, nominally scaled variables, while arithmetic mean and standard deviation ( $\pm$ ) were calculated for milk yield and LDH numbers. The least significant difference (LSD) test was used to determine statis-

tical differences between periods and farm sizes, respectively, for quantitative variables; in case of differences, pairwise t-tests were computed by applying the Bonferroni correction. For categorical variables, statistical differences between farm sizes were explored by the Chi-square test. Significance was declared at p < 0.05.

#### 3. Results

#### 3.1. Feeding Management before and after Lockdown

Before the lockdown, dairy farmers owned between 2 and 10 LDH cattle. Genotypes were crossbred Holstein-Friesian, Sahiwal, Sindhi, Jersey, and local breeds. The average milk yield was 8.2 L cow<sup>-1</sup> day<sup>-1</sup>. The majority (75%) of dairy farmers sold the milk to dairy cooperatives of which they were members; the remaining 25% sold the milk directly to private consumers and restaurants. Cattle were fed with cultivated or naturally growing green forages such as Napier grass (*Pennisetum purpureum* S.), Alligator weed (*Alternanthera philoxeroides* G.), Bermuda grass (*Cynodon dactylon* P.), Para grass (*Brachiaria mutica* S.), Water hyacinth (*Eichhornia crassipes* S.) and mixed herbaceous species (Bermuda grass, Alligator weed, Para grass, and Vetiver (*Chrysopogon zizanioides* R.)), and cultivated or purchased dry forages, mainly finger millet straw. Furthermore, 99% of the dairy farmers fed concentrate feed to their animals. While 31% of the interviewed farmers harvested or purchased (green) fodder growing on lakeshores, 28% allowed their cattle to graze on lakeshores directly. Another 38% of farmers collected grass from roadsides and in designated construction areas, and 34% allowed their cattle to graze road sides or designated construction areas directly.

Due to the lockdown restrictions, 28% of the farmers changed the amount of feed offered, the ration components, and the share of different feeds. The majority (88%) of farmers stated to cultivate more green grass after rather than before lockdown; hence, the lockdown did not affect the fodder supply from the dairy farmers' own land, but affected the supply of feed harvested on public land due to strict lockdown regulations. However, the lockdown affected the concentrate supply, with 7% of farmers not feeding concentrate after lockdown versus 1% not feeding concentrate before lockdown (p < 0.05; Figure 3). The lockdown also affected the availability of dry forage, with 33% of the dairy farmers having problems buying dry forage after lockdown versus 20% facing this problem before lockdown (p < 0.05). Grazing opportunities on lakeshores and other public land were also affected, with only 15% of the dairy farmers grazing their cattle on lakeshores after lockdown versus 28% before lockdown (p < 0.05).

The reasons dairy farmers gave for decreasing the use of some feedstuffs after lockdown were mostly unavailability due to lockdown restrictions and higher prices (Figure 4). The costs of cultivating grass by the dairy farmers themselves also increased due to the higher prices of inputs such as fertilizers. The harvest of green fodder on public lands, including lakeshores, was impossible as it was forbidden to leave the house. The market price of dry forage increased due to higher demand caused by the declining availability of green fodder and due to the restrictions of vehicle movements between states and districts.

#### 3.2. Lockdown Impacts on Herd Size, Milk Yield, and Revenue from Milk Sale

The average dairy herd size decreased from 4.5 LDH per farm with 80% lactating cows before lockdown to 3.8 LDH per farm with 73% lactating cows after lockdown (p < 0.05). On large farms, herd size decreased from 8.0 to 5.5 LDH and on medium ones from 4.8 to 4.2 LDH (p < 0.05 in both cases; Figure 5). On small farms, herd size declined from 2.6 to 2.5 LDH (p > 0.05).

Overall, 31% of the dairy farmers decreased their herd size, whereby 30% were selling off lactating cows and 5.5% sold all of their cows. The main reasons stated for decreasing herd size, and especially for selling lactating cows, were the higher prices for inputs and lower revenue for milk, as well as the unavailability of feed during lockdown. More specifically, 28% of the interviewed farmers were facing feed shortage, 18% complained about lower milk prices and higher feed costs due to higher transportation costs and general unavailability of feed, 8% struggled with a reduced demand for their milk, 31% faced a



general lack of capital for farming activities, and 15% pointed to cow health problems due to limited access to veterinary care (Figure 6).

**Figure 3.** Use of different feedstuffs (yes/no) by dairy farmers before lockdown and after lockdown establishment in Greater Bengaluru, India. BL = before lockdown, AL = after lockdown; \* Values with asterisk differ significantly at p < 0.05.



Figure 4. Reasons given by dairy farmers for not using a certain feedstuff after lockdown.



**Figure 5.** Number of lactating and dry cows and heifers before lockdown (BL) and after lockdown establishment (AL) on small, medium, and large dairy farms in Bengaluru. Contained in the box is the median, limits of the box indicate the 25th and 75th percentile, vertical lines show typical data range, and cross sign show mean values. The means of boxes with different superscript letters differ at p < 0.05.



**Figure 6.** Reasons given by dairy farmers for decreasing herd size after lockdown in Greater Bengaluru, India.

The average milk yield per cow and day was 8.2 L before lockdown and 7.6 L after lockdown, without significant differences between farm sizes (Figure 7). Across farms,

the overall daily milk yield was  $3905 \pm 19$  L before and  $2861 \pm 16$  L after the lockdown (p < 0.05). This 26% decrease was mainly explained by the decreasing number of lactating cows per herd, the explanation given by 30% of the interviewees for lower milk yield per farm. Some (14%) dairy farmers stated that they stopped milking their lactating cows earlier than normal, and 8% related the lower feed offer to reduced milk production by their lactating cows.



**Figure 7.** Milk yield (bar: mean; error bar: SD) before lockdown (BL) and after lockdown establishment (AL) on small, medium, and large dairy farms in Bengaluru. Different superscript letters indicate differences between means at p < 0.05.

The main reason for selling lactating cows was the milk price paid by dairy cooperatives, which dropped by 12% from 27 Indian rupees (INR) before lockdown to 24 INR after lockdown (p < 0.05). However, the price of milk directly sold to consumers did not change. In addition, the monetary subsidy provided by dairy cooperatives to their farmers also decreased from 5 INR before to 4.5 INR per liter of milk after lockdown. Next to selling dairy cattle, dairy farmers tried to cope with these constraints by engaging in additional income-generating activities; this applied to 25% of the interviewees and a majority thereof (73% among the 25%) took up or expanded small ruminant farming. Consequently, the number of sheep and goats kept by the survey respondents increased by 28% and 6%, respectively, after lockdown. Another 21% of the dairy farmers got more engaged in crop cultivation, or took up a job in the private sector after May 2020.

#### 3.3. Farmers' Perception of Lockdown Impacts and Coping Strategies

In the first week of the lockdown (24–31 March 2020), 78% of the surveyed dairy farmers faced problems related to their daily activities; thereof, 83% didn't have sufficient resources (money, feed, short-term milk preservation facilities) to face the shock, 13% couldn't sell milk at this time, and 4% didn't have enough information about the COVID-19 hygiene protocol for milk production, preservation, transportation, and selling during the lockdown (Table 2). After lockdown, fewer dairy farmers (20%) were affected than during the 1st week of lockdown (78% farmers) because they had adapted to the lockdown situation by using their own financial or labour resources (savings, jewelry, land, family labour) and received financial support from family members or loans from financial institutions to carry on dairy farming. When asked what they would have done differently if they had known about the implementation of the lockdown in advance, 69% of the dairy farmers didn't have any idea, but 26% claimed that they would have stored more forage. When asked how they planned to cope with COVID-19 in the months ahead, 82% of the interviewees had no specific plans, and 18% planned to store feed, sell cows, rear more small ruminants,

or intensify crop cultivation. A third of the farmers (36%) perceived the decline in milk price as the greatest challenge during the lockdown; for 31% it was the increased feed cost; and for 19% the difficulties in milk marketing due to reduced milk demand and difficulties in milk delivery to customers and the cooperatives.

**Table 2.** Problem perception and mitigation strategies of dairy farmers before and after different phases of lockdown in Bengaluru (n = 129).

Question	Answer	Frequency (%)
Mille marketing problems during first weak of last down	No	78
Mink marketing problems during first week of lockdown	Yes	22
Milk marketing problems after lockdown	No	90
wink marketing problems after lockdown	Yes	10
Form management problems during first week of lockdown	No	22
Faint management problems during mist week of lockdown	Yes	78
Form management problems after lockdown	No	80
Farm management problems after fockdown	Yes	20
Process for decreasing impact of lockdown over time	Adaptation of resource use	63
Reasons for decreasing impact of fockdown over time	Support by family or bank loan	37
	No idea	69
Shock mitigation strategies before lockdown	Feed storage	26
	Reduction of herd size	5
	No idea	82
Shock mitigation strategies after lockdown	Feed storage	8
Shock infugation strategies after lockdown	Reduction of herd size	5
	Shift to company job, crop farming, sheep and goat farming	5
	Lower milk price	36
	Higher feed cost	24
Greatest challenge during strict and partial lockdown phases	Don't know	17
	Difficulty selling milk	14
	Higher management costs (veterinary care, labour, transport)	9

#### 4. Discussion

The pandemic caused by the novel SARS-CoV-2 (COVID-19) virus has put enormous pressure on global health systems, economies, and social life. Such effects were also noted for the 2018 pandemic influenza in the United States of America. To handle the mild influenza pandemic situation, the total cost was US dollars 374 billion, to handle severe influenza pandemics US dollars 7.3 trillion; the 2003 SARS outbreak in East and Southeast Asia led to losses of US dollars 12–28 billion [8]. Yet, also at the individual level, economic losses due to pandemic situations can be severe: in April 2020, dairy farmers were forced to dump 4 million gallons of milk in the United States of America [43], and in Nepal, damage to dairy products was about US dollars 17 million [44]. Additionally, the daily losses to the Indian dairy sector during the strict lockdown time were about US dollars 9 million. Such economic losses indicated that the investigation into the impacts of COVID-19 on small-scale dairy farming level [28] should be carried out.

The COVID-19 pandemic severely affected dairy farmers in Bengaluru, in terms of their regular access to cattle feed on their own and public land, dairy herd size, milk production, marketing, and longer-term dairy management strategies. First, the lockdown impacted the feeding strategies of dairy producers: the availability of green forage decreased because dairy producers were scared of COVID-19 and obliged to the strict movement restrictions imposed across the city, which impeded the collection of fodder from lakes and public spaces. Likewise, availability of dry forage shrank significantly due to transportation restrictions; being a generally important resource during the dry season [45], finger millet

gained even greater importance during the lockdown because of the lower availability of other feeds, which increased its price [33]. The price of commercial concentrate feeds was also rising due to the impacts of COVID-19 on feed value chains [8,33]. Similar impacts of the lockdown on feed availability and price were also reported from the United States of America [46], Pakistan [47], China [46], and Ethiopia [48]. Globally, for dairy production, disruptions in feed supply were reported for soybean meal, wheat bran, oil cake, and hay [49].

The second severe problem for Bengaluru's dairy farmers was decreased milk demand after lockdown implementation. On the one hand, consumers purchased less milk due to movement restrictions [28]; on the other hand, the shutdown of trade, industries, government services, and educational institutions and their canteens and catering services further decreased the demand for milk and milk products [46]. Given the lower demand for milk, Indian dairy plants collected and processed less milk and reduced the price paid to milk producers by 35–40% on average [33]. Similarly, in neighbouring Bangladesh, the milk price declined by 17% due to COVID-19 [23]. Further milk price declines were reported from Pakistan [47], Canada [18], and the United States of America [46,50]. Consequently, milk dumping by farmers was reported from Canada and the United States of America [51,52] and even in Indian farmers were discarding milk in the absence of procurement [33]. In Kenya, by contrast, the milk price did not decrease because the dairy cooperatives supported their dairy producers by paying the same price as before the lockdown [49]. As a reaction to the declining milk price, dairy herd sizes in Bengaluru decreased, mainly on medium and large farms, because dairy producers sold dairy cows as a mitigation strategy. In consequence, the average milk yield per farm decreased, but the daily milk yield per cow was not affected. A decline in daily milk yield per cow was reported from Pakistan due to lower feed input [47], and for Bangladesh, a reduction of cows' daily milk yield by 2.6 to 3.3 L was estimated [23]. In Kenya, the national milk yield declined due to normal seasonal variation, but herd size did not change because selling cows was difficult for farmers during lockdown with closed markets, and the milk price stayed at the pre-lockdown level [49].

Overall, milk marketing problems in Bengaluru were more severe at the start of the first lockdown. Later on, farmers implemented lockdown mitigation strategies for their dairy herd management, and dairy cooperatives published a COVID-19 hygiene protocol on a notice board for dairy production and milk delivery, in addition to the city authorities' hygiene protocol for the general population. Farmers started to utilise existing financial and labour resources within their families and bank loans to carry on dairy farming. The American small dairy farmers were given financial support under the Paycheck Protection Program to overcome the COVID-19 crisis [46,50]. Similarly the World Bank had previously sanctioned grants and loans for Ebola responses to rebuild health, agriculture, and social safety nets [53].

Taken together, our farmers' responses point to a decrease in farm revenues due to lower milk production per farm, lower milk price, higher feed costs, less feed availability, and higher cost of services related to dairy farming, such as veterinary care. Similarly, Uddin et al. [23] estimated a decline in daily farm revenues ranging from 1.9 to 4.7 US dollars per farm for dairy producers in Bangladesh. In Bengaluru, the majority of the interviewed farmers did not have clear ideas on how to mitigate the shock. Only a few claimed that having stored feed and reduced herd size before lockdown would have helped mitigate the shock. Moreover, about two-thirds of the farmers stated that the reduced milk price and higher feed costs were the main obstacles to overcoming the shock, and the use of additional resources could only partially mitigate it. Dairy producers' strategy to engage in informal or formal jobs and/or intensify and diversify agricultural activities such as crop cultivation and small ruminant rearing were also reported from different sources [54]. However, lower milk production per farm diminished not only farmers' dairy revenues but also the farming household's own milk consumption, potentially threatening the nutritional status, especially of vulnerable members [55,56].

In India, dairy cooperatives and private processors reduced milk collection and processing drastically because of the lower demand for processed products with short shelf-life, e.g., ice cream or *curd* (yoghurt) [33]. To mitigate the milk market shock, dairy cooperatives and related companies could have processed the extra milk into products with longer shelf-life, such as butter, *ghee* (clarified butter), skimmed, or powdered milk [57]. A few processing units reported a higher demand during lockdown for *paneer* (fresh cheese; shelflife between 3 to 21 days), often used in Indian dishes [58]. Processing of extra milk into products with a longer shelf-life was constrained by processing capacity [59], however, and the lack of storage facilities [60]. The selling of processed dairy products, often bought by convenience, is also constrained by the strong preference of Indian consumers for fresh milk, which is then bought directly from dairy producers and processed at home [61]. Harvesting of added value through processing by dairy producers themselves might thus be a limited mitigation strategy to milk market shock. To mitigate limited feed availability, dairy cooperatives and other institutions could train farmers in feed conservation practices and support communal infrastructure for drying, ensiling, and storing forages [62]. A shock management fund or disaster management insurance might be another option to support farmers in case of drought, flood, pandemics, and other calamities [63]. The advantages of such a fund can be seen regarding the support the Mongolian livestock sector receives during extremely cold winters [64] or of general insurance schemes in support of Indian crops and livestock [16,65].

# 5. Conclusions

The analysis of dairy farmers' problems with and reaction to the COVID-19 lockdown imposed in Bengaluru demonstrates that these farmers were willing and able to maintain their daily activity in the midst of a severe crisis and thus continued to supply fresh milk to consumers in and around the megacity. We found that, following the lockdown, the share of farmers feeding concentrates decreased while those feeding dry forages increased significantly. Milk yield dropped in all surveyed farms as dairy farmers sold lactating cows to cope with higher prices for inputs as well as the unavailability of feed during lockdown. In addition, lower milk prices, especially at dairy cooperatives, became a crucial problem for dairy farmers. However, the role of the dairy cooperatives, which are very important in India, could have been more proactive and, in addition to the elaboration of sound milk-hygiene concept, could have advised farmers on forages conservation and processed surplus milk into products with longer shelf-life. Furthermore, setting up shock mitigation funds or offering insurance to their members are policies to be explored with a view to better coping with future calamities.

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**Data Availability Statement:** For scientific purposes, data can be made available to individual scientists upon written request to the first author.

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Conflicts of Interest: The authors declare no conflict of interest.

### Appendix A

**Table A1.** Description of variables used to understand the impacts of COVID-19 lockdown on small-scale dairy farmers in Greater Bengaluru, India.

Variables	Description
Socio-economic of the household	
Household size	Total number of household members
Head of household: age, gender, marital status, education, employment	Characteristics of the household head
Importance of dairy as an income for the household	Dairy production is the only income/Dairy production is the main income amongst others/Dairy production is a complementary income/Dairy production is not an income/Don't know or prefer not to answer
Dairy herd	
Lactating cow	Number of cows currently milked
Dry cow	Number of cows currently dry
Heifer	Number of heifers, defined as pregnant or already inseminated once
Feeding strategy	
Concentrate	Supply of concentrate per day and animal, in kilograms
Green forage	Supply of green forages per day and animal, in kilograms
Dry forage	Supply of dry forage per day and animal, in kilograms
Cutting grass	Supply of grass cut from lake shores per day and animal, in kilograms
Grazing	Daily grazing on the lake shores, in hours
Public land	Use of other public grounds, e.g. road side areas, for grazing (yes/no)
Own land-Grazing	Use of own farm land for grazing (yes/no)
Own land-Cultivation	Use of own farm land for cultivating forages (yes/no)
Milk production and marketing	
Milk production	Milk production per day and animal, in liter
Milk price	Milk price per liter, in Indian rupee
Milk marketing	Marketing channels used to sell milk, e.g. dairy
Challenges due to COVID-19 lockdown	cooperative, neighbourb, inflationali
Challenges	Greatest challenges during COVID-19 lockdown (open question)
enunenges	Change in feeding strategy (decrease /increase of each type of
Feeding strategy	feedstuff) and reasons
Herd's in-and outflow	Number of dairy cattle born/bought/sold/dead since the first
	lockdown and reasons
Milk production	Change in milk production (decrease/increase) and reasons
Shock mitigation	Strategies for shock mitigation in the coming months (open question)

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