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A review on mechanization of dairy farming

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Abstract
The role of new emerging dairy technologies in rural areas is crucial for Indian livestock farming. According to a review, only 10% of dairy farming in India is mechanized, which is very low compared to the current trends. The most common automatic systems used in animal production have various objectives (Cattaneo, 2009), such as automatic identification, drafting, feeding, milking, estrus detection, birth detection and many other farm operations. Mechanization can bring benefits such as reduced labour and time, increased milk and meat production, improved milk quality, enhanced animal welfare and increased profitability and sustainability. However, dairy farmers face many obstacles to adopt mechanization, such as high cost of machines, lack of skilled manpower and technical support, lack of awareness and knowledge among farmers etc. These technologies can minimize the negative factors and maximize the positive factors that influence milk production, while using minimal resources.

Keywords: Dairy mechanization, farming, technology, automation

1. Introduction
Dairy farming is one of the most important sectors of Indian agriculture, as it provides livelihoods to millions of rural households and contributes to the country's food security and nutrition. According to the latest data from the Department of Animal Husbandry and Dairying, India has the largest bovine population in the world, with about 303 million cattle and 148 million buffaloes as of 2019. India is also the largest producer and consumer of milk and milk products, with an estimated production of 198 million tonnes in 2019-20.

Dairy farming is one of the major sources of livelihood and income for rural households in Maharashtra, especially in the drought-prone regions of Vidarbha and Marathwada. However, the dairy sector faces many challenges, such as low productivity, poor quality, high input costs, inadequate infrastructure, lack of market linkages, and environmental issues(1). To overcome these challenges and meet the growing demand for milk and milk products, there is a need for mechanization and modernization of dairy farming in Maharashtra as well as in India.

The dairy industry began to mechanize as early as 1830 (Shahhosseini, 2013), but only recently have there been significant advances in dairy farm mechanization due to the rise in the number of animals per farm. Automation is very important in modern dairy farming; it has enabled dairymen around the world to adopt new and innovative technologies to increase their farm's output and profit. Many technological innovations have enhanced the milking process greatly, but feeding automation has not progressed much. If the feeding operations were fully mechanized and automated, the labor productivity would increase by reducing labor and labor costs and freeing up more time for other farm tasks (Svennersten-Sjaunja and Pettersson, 2008; de Koning, 2010) [53, 18].

Mechanization of dairy farming refers to the use of machines and equipment for various activities involved in dairy production, such as milking, feeding, cleaning, cooling, processing, packaging, and transportation (Jacobs and Siegford, 2012) [25]. Mechanization can help improve the efficiency, quality, profitability, and sustainability of dairy farming by reducing drudgery, saving time and labour, enhancing animal health and welfare, increasing milk yield and quality, reducing wastage and spoilage, adding value to the products, and minimizing environmental impacts.

The level of mechanization in dairy farming in India is still low compared to other countries. According to a study by the National Dairy Development Board (NDDB), only about 10% of the dairy farmers in India use mechanized milking systems. The majority of the dairy farmers still dependent on traditional methods of milking by hand or using simple devices like rubber tubes or buckets. The use of other types of machinery and equipment for feeding, cleaning, cooling, processing, and transportation are also limited.

The main factors that hinder the adoption of mechanization in dairy farming in India are:

- Lack of awareness and knowledge among farmers
- Lack of availability and accessibility of machines and equipment
- High cost of machines and equipment
- Socio-cultural barriers and resistance to change
- Lack of credit facilities and subsidies
- Lack of standardization and quality control
- Lack of skilled manpower and technical support
- Lack of proper maintenance and repair services

However, there is a huge potential for growth and development of mechanization in dairy farming in India, as the demand for milk and milk products is expected to increase in the future due to population growth, income growth, urbanization, changing consumption patterns, and health awareness. According to a projection by NDDB, the demand for milk in India will reach 292 million tonnes by 2023, which will require an increase in milk production by about 47% from the current level.

To achieve this target, there is a need for enhancing the productivity and quality of dairy farming through mechanization. Some of the possible benefits of mechanization in dairy farming are:

- **Increased milk yield per animal:** Mechanized milking systems can help increase the milk yield per animal by stimulating more frequent and complete milking, reducing stress and injury to the animals, improving udder health and hygiene, preventing mastitis and other diseases.
- **Improved milk quality:** Mechanized milking systems can help improve the milk quality by reducing contamination from dirt, dust, bacteria, somatic cells, etc., maintaining optimal temperature and pH levels, preserving freshness and shelf life, ensuring compliance with quality standards.
- **Reduced labour cost:** Mechanized milking systems can help reduce the labour cost by saving time and effort required for milking, reducing dependence on hired labour, freeing up labour for other productive activities.
- **Enhanced animal welfare:** Mechanized milking systems can help enhance animal welfare by providing comfort and convenience to the animals, reducing pain and discomfort during milking, allowing natural behaviour patterns, improving feeding and nutrition, reducing mortality and morbidity rates.
- **Increased profitability and sustainability:** Mechanized milking systems can help increase profitability by increasing milk yield and quality, reducing labour cost, reducing input cost (such as feed, water). It can also reduce the environmental impact of dairy farming by minimizing the greenhouse gas emissions, water consumption, and nutrient losses from manure.

The demand for milk and milk products in India is likely to grow in the future because of factors such as population growth, urbanization, income growth, changing consumption patterns, and health awareness. This creates many opportunities and prospects for mechanization in dairy farming in India. However, to address these challenges and seize these opportunities, there is a need to improve the policy support and incentives, the delivery mechanism and institutions, the rural infrastructure and services, the collaboration and innovation among stakeholders, and the knowledge and skills of the farmers. Therefore, the farmer should plan and implement mechanization in dairy housing carefully, considering the farm objectives, resources, and constraints. The farmer should also assess the costs and benefits of mechanization and compare different options and alternatives before making a decision.

Mechanization in dairy farming in Marathwada region has also seen some positive examples and opportunities. For instance, the Vidarbha and Marathwada Dairy Development Project (VMDDP) is being implemented by the National Dairy Development Board (NDDB) in collaboration with the Government of Maharashtra, which is improving the livelihoods of small and marginal dairy farmers in the drought-affected areas of Vidarbha and Marathwada. The project has increased the income of more than 91,000 farmers by ensuring fair consumer price, establishing milk procurement infrastructure, supplying quality cattle feed and mineral mixture, training farmers in silage making, and creating market linkages. The project has also adopted mechanized milking systems, automatic cooling systems, automatic water drinking systems, biogas plants, fodder chopper machines, and solar water heaters to enhance the efficiency and quality of dairy production.

The local market offers and promotes various types of agricultural machinery and equipment. A farmer to farmer extension program, supported by cooperative and accessible information, enables farmers to acquire new machinery tools easily. However, mechanization also increases the inputs and production costs for farmers, especially in the initial period of using a new machine. Although mechanization boosts the number and productivity of dairy cows, it does not affect the farm income growth of farmers who mechanize compared to those who do not. Farmers seek to mechanize their farming to achieve higher and better yields, more income and employment opportunities. Yet, the high investment cost of machinery poses budgeting challenges for farmers and discourages small farmers from mechanizing their farming (M H Haridana *et al*., 2019) [37]. Moreover, small farmers face many constraints that limit their response to mechanization. They contend that machinery equipment demands skilled labor, maintenance, and depreciation, which reduce their performance and value over time. Therefore, the main objective of this review was to explore the effects of technological changes and innovations and their applications.

Recent advancement and development of machineries in dairy farming

Mechanization and automation in dairy farms depend on the size of the herd and the availability of labour. Dairy farms are more likely to use mechanization as the average number of cows rose by 37.5% (Khanal *et al*., 2010) [30]. The degree of mechanization also affects the modern and innovative technologies for dairy cattle breeding. This article presents modern solutions for dairy cattle breeding, especially for livestock buildings, which can be extended lengthwise according to the farm's needs and can produce extra energy from biogas and post-ferment for granulated organic fertilizer. The technology for milk production that is examined involves methane fermentation, biogas production, and fertilizer production in the shape of granules. The modular cattle breeding technology that is shown includes sustainable production, which is economical, eco-friendly, with animal welfare conditions in the facility, and socially acceptable, due to the high level of mechanization, which ensures both comfortable work environment and high milk quality. The production line that is shown is a vital part of the milk production process that can use organic fertilizer for producing healthy food. (Waclaw Romaniuk *et al*., 2021) [58].

The livestock industry is increasingly adopting automatic technologies, which have a significant impact on the future outlook. The automatic systems that are widely used in animal production aim at various objectives (Cattaneo, 2009) [14], such as automatic identification, sorting, feeding, milking, estrus detection, birth detection and many other farm tasks. Automated Milking Systems (AMS) offer appealing benefits of lower labor requirements and better social conditions for the dairy farmers. Other possible benefits are enhanced animal health and welfare and increased milk production. (Y Bhavya *et al*., 2018) [60]

As P.J. Galama *et al*., (2020) [45] describe, the housing systems for dairy cows have changed recently and are likely to change more in the future. These new changes aim to create a suitable production environment for modern high-producing dairy cows and support related improvements in management, agro-technology, and equipment for dairy farming. The need for higher labor efficiency led to the transition from tie-stall barns to cubicle barns (or free stall barns). To address future needs, new ideas beyond cubicle barns have to be developed. Free walk housing systems, which are loose housing systems without cubicles, could meet some of these future needs. These systems use composting bedding material or artificial permeable floors as lying and walking areas. However, these barns are not fully developed yet. Combinations of cubicle and free walk housing systems, along with other techniques under development, could become a major future housing system. Other techniques and systems that are being evaluated based on sustainability criteria include the multi-climate shed, the Cow Toilet (Hanskamp Agro-Tech, Doetinchem, the Netherlands) to separate feces and urine, and multifunctional buildings. These buildings and techniques can belong to land-based or, less frequently, city-based farming systems, such as floating farms.

Muhammad Osama Akbar *et al*., (2020) [38] explores various aspects of smart dairy farming and proposes a state-of-the-art framework that can help farmers increase their milk yield by using different advanced technologies. To cope with the growing demand for milk products, better technological techniques for enhancing milk yield are needed. The authors expect that IoT and various AI techniques can help a farmer overcome different traditional farming difficulties and boost the milk production. In this research, they address different challenges that a dairy farmer encounters in everyday life. They present a brief introduction of smart dairy farming (SDF) in relation to the innovation in production and the processes of smart dairy farming. These technological methods can reduce the factors that negatively affect milk production and increase those that positively affect production with minimal resources.

M H Hadiana *et al*., (2019) [37] examines the effect of mechanization on small dairy farms. Mechanization is a crucial factor for maintaining production in the dairy sector, where the production system is becoming more oriented towards agribusiness. The dairy farming sector in Indonesia is mainly composed of small farmers who have not adopted labour-substitution technology to improve their farming. The authors conducted a survey in two dairy primary cooperatives in West Java. They collected data from 111 dairy farmers who had at least five dairy cows each, selected randomly. The findings indicate that using farm machinery for milking cows and processing forages significantly increases the herd size. Furthermore, the larger herd size depends on the farmers' ability to operate a few machines to manage various farm activities. Mechanization results in more dairy cows with little increase in farm labour. This labour-saving practice is needed by this sector, especially to assist small dairy farmers who want to expand their farming size, while labour costs are rising.

The livestock sector employs rural people throughout the year. A dairy farm relies on three production factors or primary resources: land, labour and capital. Labour is the most vital resource and its cost is second only to the cost of feed (15-20% of total farm expenses). The most labour intensive operations in a dairy farm are milking, feeding and cleaning. Milking process requires the most labour (more than 50%), and the amount of labour needed for milking depends on the milking methods. Feeding is the next most time-consuming operation, requiring 25% of labour. Calculating the labour needed for different dairy farm operations and expanding the herd size can help prevent the misuse of labour force. Loose housing system also lowers the labour requirement compared to traditional housing system. (M Sathiyabarathi *et al*., 2015) [36]

They selected the most mechanized RDA dairy farm and the rest of the non-mechanized farms for this study. Most of the farms lacked specific farm building design with specific space per animal, feeding alley, manger, gutter and drainage system, ventilation system. The manure management system in the study area was also very poor. A biogas plant could properly use the manure. Only BAU and RDA dairy farms had milking machine and chopper machine. The space per animal for dairy cow, pregnant cow, dry cow or heifer, and calf were 3.65 m2, 9.30 m2, 1.37 m2, and 1.31 m2 respectively. The mangers in a pen barn varied from 0.5-1.25 m in width and 0.5-1 m in depth for dairy cow, heifer, calf, and bull individually. All farms in the study areas had natural ventilation system. The daily concentrates needed for dairy cow, dry cow, heifer, bull calf, cow calf and mature bull were 3.4, 2.2, 1.2, 0.5, 1.01 and 5.2 kg respectively. The maize amount for bull, dairy cow and bull calf were 2.4 kg, 1.4 kg and 140 g per head respectively. Farmers did not adopt machinery like milking machine, chopper machine etc. due to lack of knowledge and familiarity. Partial mechanization could help transform indigenous into modernized with high productivity of dairy farming systems in Bangladesh.

Jagubhai Makavana and Piyushkumar Balas., 2019 [26] examines the impact of advanced mechanization dairy farming technology on increasing milk production, reducing poverty and hunger, preventing diseases and ensuring environmental sustainability in developing countries such as India. They used like rt scale methodology to analyse the constraints of modern dairy technologies, such as maize chopper, disc mower, drum mower, milking machine and total ration mixer machine. Based on rank order and weighted mean value, they found that high initial cost was the main constraint, followed by unavailability in local market, high maintenance cost, lack of awareness, low reliability, lack of skills, after sales services, no need and difficulty in finding spare parts.

Automatic Milking System

An automatic milking system is a device that can milk cows and other dairy animals without human intervention. It uses a robotic arm to attach the teat cups, sensors to check the health and quality of the milk, and a computer to manage the whole process. Automatic milking systems can provide many advantages for dairy farmers, such as saving time, enhancing animal welfare, and boosting milk production. However, they also have some drawbacks, such as high initial costs, maintenance needs, and adaptation to different farm systems. AMS emerged in the late 20th century and have been commercially available since the early 1990s. AMS can provide many advantages for dairy farmers, such as saving time, enhancing animal welfare, and boosting milk production. However, they also have some drawbacks, such as high initial costs, maintenance needs, and adaptation to different farm systems. AMS also need specific guidelines and standards to ensure the safety and quality of the milk and the welfare of the animals.

A.Castro *et al*., (2012) [4] The evaluated the AMS capacity in each farm under real working conditions by analysing milking data of 34 single AMS units on 29 Galician dairy farms. They used various parameters, such as number of cows, milk yield, milking frequency, actual milking time, rejected milking time, cleaning time, and machine downtime, to determine the optimal number of cows per AMS unit and the optimal milking frequency and milk production. The results showed that an AMS unit milked 52.7±9.0 cows daily at 2.69±0.28 milking frequency, with a total milking downtime of 1,947±978 h/yr and a milk yield of 549,734±126,432 kg/yr. The cow number and milk flow rate were the most influential predictors of the milk yield per AMS, explaining 87% of the variation. The authors suggested that the AMS in Galician dairy farms could accommodate an additional 16±8.5 cows per AMS without compromising milking performance, which could increase the annual milk production per robot by 185,460±137,460 kg. This could accelerate the return on investment of the system. The authors also recommended that the daily milking throughput could be optimized at 2.4 to 2.6 milking frequency.

G. H. Klungel *et al*., (2000) [21] examined the effect of automatic milking systems (AMS) on milk quality on 28 Dutch dairy farms and compared the results with milk quality parameters on two groups of farms using conventional milking parlors (CMP) with either two (49 farms) or three (28 farms) milking sessions per day. The introduction of AMS led to a significant increase in total bacterial plate count (TBC) and free fatty acids (FFA). TBC, FFA, and freezing point (FP) were higher on farms with AMS than on farms with CMP. Somatic cell counts (SCC) did not change after the introduction of AMS, but were already relatively high on farms with AMS compared with farms with CMP. The use of AMS in the study reduced milk quality compared with the use of CMP.

G. G. N. Hermans *et al*., (2003) [22] studied the behaviour of all cows and two subsets of cows with different frequencies of visits to the AMS: 8 low frequency cows vs. 7 high frequency cows. They observed the cows for 72 h in each of two situations: Semi-forced traffic and forced traffic. They recorded the cow locations and behaviour at 10-min intervals for all cows and individually for the subsets. In semi-forced traffic, the herd easily accessed the forage feeding area, spent more time eating (17.4% vs. 15.1±0.59% of the day), and less time standing in freestalls (9.0 vs. 11.8±0.30%) than in forced traffic. Non-milking visits to the AMS tended to decrease, while milking visits stayed the same in semi-forced traffic. The high frequency cows had fewer non-milking visits (1.8 vs. 4.2±0.7) in semi-forced traffic, while the low frequency cows had a non-significant increase (1.5 vs. 1.0) in non-milking visits. The high frequency cows used the forage feeding area and the adjacent lying area more than the low frequency cows and increased their use of those areas in semi-forced traffic. The authors concluded that semi-forced traffic was more preferable than forced traffic for both cow welfare and AMS capacity.

C. A. Rotz *et al*., (2003) [13] used a farm-simulation model to evaluate the long-term, whole-farm effect of adopting AMS on farms with 30 to 270 cows. They reported that the highest potential economic benefit was a single-stall AMS on a 60-cow farm with a moderate milk production level (8600 kg/cow), compared with new conventional milking systems. They estimated losses in annual net return of $0 to $300/cow for other farm sizes using single-stall robotic units, with the largest losses for larger farms and higher milk production (10, 900 kg/cow). Systems with one robot serving multiple stalls had a higher net return than single-stall systems, and this net return was similar to traditional parlours for farms with 50 to 130 cows. The potential benefit of AMS increased by $100/cow per year if the AMS increased production by another 5%. A 20% reduction in initial equipment cost or doubling milking labour cost also increased annual net return of an AMS by up to $100/cow. However, annual net return decreased by $110/cow if the economic life of the AMS was reduced by 3 yr for a faster depreciation than that typically used with conventional milking systems. The authors concluded that, under current assumptions, the economic return for an AMS was comparable to that of new parlour systems on smaller farms when the milking capacity of the AMS aligned well with herd size and milk production level.

J. A. Jacobs and J. M. Siegford (2012) [25]. The authors studied the stress behaviour of cows after the introduction of AMS. They observed four stress-related behaviours during milking by trained observers, while the AMS automatically recorded the milk yield. Within a month of introducing the cows to the AMS, more than 60% of the herd on day 8 and 95% of the herd on day 30 were milking voluntarily, suggesting that the cows did not find the AMS aversive. However, more elimination and vocalization behaviours and lower milk yield on day 0 indicated initial stress and discomfort with the new milking system. The authors also reviewed the impact of AMS on dairy cow welfare. AMS could potentially increase milk production by up to 12%, reduce labor by as much as 18%, and improve dairy cow welfare by allowing cows to choose their milking time. However, these expected benefits may not be fully realized by producers using AMS for various reasons. Since the introduction of AMS in the market in the 1990s, research has compared AMS with conventional parlours, mainly focusing on cow health, milk yield, and milk quality, as well as some economic and social factors related to AMS adoption. Moreover, because AMS rely on voluntary cow visits, research has also examined the behaviour of cows in AMS facilities, especially cow traffic around AMS, cow use of AMS, and cow motivation to enter the milking stall. However, the sometimes inconsistent results from different studies on the same aspect of AMS indicate that management and farm-level variables may have more influence on AMS efficiency and milk production than milking system features.

As new AMS designs, such as the automatic rotary milking parlour, continue to emerge in the dairy industry, research needs to continue on AMS to understand the causes and effects of differences between milking systems and the impacts of the different facilities and management systems that accompany them on dairy cow behaviour, health, and welfare.

W. Steeneveld *et al*., (2012) [59] assessed the technical efficiency of farms with an automatic milking system and conventional milking system. Switching from a conventional milking system (CMS) to an automatic milking system (AMS) requires a new management approach and a corresponding change in labour tasks. A clear replacement of labour with capital with the adoption of an AMS was not observed. The AMS farms had a slightly lower technical efficiency (0.76) than the CMS farms (0.78), but this difference was not significant. This implies that the farms were not different in their ability to use inputs (capital, labor, cows, and land) to produce outputs (total farm revenues). The technical efficiency of farms that invested in an AMS in 2008 or earlier was not different from the farms that invested in 2009 or 2010, indicating that there was no learning effect during the transition period. The results indicate that the economic performance of AMS and CMS farms are similar. These results show that apart from higher capital costs, the use of AMS instead of CMS does not affect farm efficiency and that there are no learning costs to use an AMS as measured by any decline in technical efficiency.

J. Jago and K. Kerrisk (2011) [28] investigated two levels of training before calving on the behaviour of cows and heifers in an extensive pasture-based AMS. Animals received either no training (NIL), training that included handling, in the AMS and on-farm gating system (MINIMAL) or training in the AMS that included exposure to typical noises and mechanical movements, plus on-farm gating system (EXTRA). Regardless of the level of training, heifers learned to use the on-farm gating system and achieved their first voluntary milking faster than cows (Time to milking: Heifers = 1.88 d, Cows = 2.55 d, SED = 0.18, $p< 0.001$). Pre-calving training improved aspects of the behaviour needed for successful adaptation to automatic milking but had little impact on time to achieve a voluntary milking. Heifers adapted faster than cows to automatic milking in a pasture-based farming environment.

C Wenzel *et al*., (2003) [17] observed the behaviour and stress response of cows during milking in an automatic milking system compared to those milked in a milking parlour. Step behaviour happened significantly more often in the milking stall of the automatic milking system than in the milking parlour. The heart-rate of cows milked automatically increased significantly between minute 5 and minute 1 before entering the milking stall. The mean milk cortisol concentration of cows milked in the automatic milking system was much higher than that of the control cows milked in the parlour. The results show a difference in behavioural and physiological condition between cows milked in an automatic milking system and in a milking parlour. The reasons for this have not been identified yet. Further studies could focus on the differences in the two milking systems.

Automatic feeding system

The popularity of automatic feeding systems (AFS) with railed or self-propelled feeders has increased over the last 5-20 years (Barmore, 2002) [11]. Recently, research centers (Kazumoto, 1999; Tamaki, 2002) [33, 54] and manufacturers (Hollander *et al*., 2005) [24] have developed different types of AFS that are usually based on either existing technologies for automated distribution of single feedstuff such as concentrates, silages and forages or on completely new concepts such as TMR or PMR. Feeding rations that are totally or partially mixed are expected to increase cow activity and encourage visits to both the feeding devices and the automatic milking system to reduce labour demand in farms (Bisaglia *et al*., 2010; 2013) [12].

R. Oberschätzl *et al*., (2015) [48] examined the electrical energy consumption of AFS on four Bavarian farms. They noted that increasing automation and mechanization can lead to higher energy consumption and costs. They also suggested that the costs incurred should be compared with the costs of diesel when feeding with a fodder mixing wagon. The results of the daily electrical energy consumption showed a wide range of 8.8 kWh for a semi-automated feeding system and 52.6 kWh for a fully-automated system. However, in the observed dairy farms, the transport of fodder from the stock container to the mixer and the mixing of the rations accounted for 77% of the total energy consumption of the AFS. A comparison of the total energy costs of feeding with an AFS and the costs incurred when feeding with a fodder mixing wagon showed that energy costs for feeding can be saved up to 40 € per livestock unit and year by using an AFS. The automation enables the use of renewable and sustainable sources of electricity generation in agricultural farms. This makes it possible for a farmer to remain competitive despite rising energy costs and declining subsidies for solar power.

Kunal Bachhav *et al*., (2023) [31] designed and developed an automatic feeding machine which is specially designed for distributing feed to a large number of animals on a farm or any other facility. In this project, they introduced an automatic cattle feeding system where food feeder follows the path through a predetermined distance and places the feed to the cattle by the side of the feed fence using conveyer system. They developed a prototype using automation unit interfaced with controller i.e. IOT that tracks the conveyer system to follow. They interfaced the motors to operate in either direction. They operated a hopper door to place the feed. They also added a controller- based switching feature for manual intervention. As a result, the developed automatic cattle feeder system can track and distribute the feed in specified path and distance respectively.

M. Parthasarathy *et al*., (2022) [39] designed and fabricated an AFS which is a new practical and modern concept to overcome the challenges due to labor shortage and to increase the white revolution. The main benefit of this machine is to do the work more efficiently to replace the manual source. The AFS relies on the programmable logical Control method. The basic work done by the AFS machine is to grab the fodder from the stockyard to cutting machine through conveyer and then the feed which has to be given to the cattle is cut as per the required conditions, then the feed is directed to the feed distributor chamber through conveyer. This system also serves the cattle at proper interval of time. It resulted in a very high feeding frequency that disturbs the cows during their resting periods and this may affect both animal comfort and milk production, to improve feeding management and the productivity and comfort of lactating dairy cows. Saran Kumar *et al*., (2021) [56] designed and built the automatic animal feed system for cattle breeds that would operate on a conveyor basis through the use of this system. It will provide schematics to be used for the wiring of the system, image and procedures for the construction of an aesthetically pleasing and useful outer-casting. Here an effort is made to develop a labour/time saving automatic feeder that will optimize feeding of birds. There are many automated equipment's to feed birds in large scale poultries. But it is difficult or impossible to include large scale equipment's in small medium scale poultries.

De Vries *et al*. (2005) investigated the effect of feed delivery frequency on cow behaviour and reported that frequent feed delivery improved feed access for all cows, especially during peak feeding periods when fresh feed was available, and reduced feed sorting. They also found that delivering the feed 6 hours after milking increased the daily feeding times of the cows by 12.5% compared to delivering the feed at milking time in a conventional system. The authors compared conventional feeding (CF) with automatic feeding (AF) on 80% of the farms in the Netherlands and observed that CF farms distributed the feed once per day and pushed up the feed 3.5 ± 1.6 times per day, while AF farms distributed the feed 7.8 ± 2.0 times per day with 3.1 ± 0.9 hours between feedings and pushed up the feed automatically. The authors also reported that the farmers using AF were satisfied with their overall performance, especially with the management aspects. They noted that AF reduced the labour requirement for feeding from 33.2 s per cow per day with CF to 16.4 s per cow per day with AF. The daily time required for using the management system differed by about 1 s per cow between the two groups of farms, ranging from 14.3 s per cow with CF to 15.4 s per cow with AF. Bisaglia *et al*., (2013) [12]

Grothmann *et al*., (2010) assessed the working time in 18 different farms in European countries using automatic feeding (AF) techniques. They considered ration management, daily storage container filling and daily feed table cleaning as the main tasks. The working time of AF in a farm with 60 animals was 50.6 MP min/day and in a farm with 120 animals was 65.2 MP min/day. In contrast, feeding the same herd with a feeder mixer wagon, which involved feed distribution and feed pushing three times, would require 71.3 MP min/day for 60 animals and 202.8 MP min/day for 120 animals.

M. Arul Prakash *et al*., (2015) addressed the issue of labour efficiency in dairy farms and suggested that automation may enhance farm efficiency and animal welfare. They noted that feeding more than 50-100 cows requires more labour and labour cost. They proposed that automatic feeding of dairy animals with forage, silage, concentrate, or TMR could reduce the feeding frequency and working time, as well as the wastage of feed, labour, and labour cost, compared to conventional feeding systems without automation.

Andrea Pezzuolo *et al*., (2016) conducted a comparative analysis of the functionality of two systems, conventional feeding (CFS) and automatic feeding (AFS), for preparing and distributing the total mixed ration (TMR). They measured energy consumption and labour for both systems. They reported that AFS was an innovative way to reduce labour requirements and improve quality and consistency of work when feeding TMR. They found that labour decreased from 2.5 h•day-1 with CFS to 1.02 h•day-1 with AFS. They also found that AFS reduced the costs and energy consumption for preparing and distributing the TMR. The costs and energy consumption of CFS were 1.44 EUR•m-3 and 0.16 EUR•cow-1 per day, and 24.66 kWh•m-3 and 2.74 kWh•cow-1 per day, respectively. The costs and energy consumption of AFS were 0.91 EUR•m-3 and 0.10 EUR•cow-1 per day, and 6.81 kWh•m-3 and 0.76 kWh•cow-1 per day, respectively.

Vikram Mali *et al*., (2022) designed and fabricated an automatic cattle feeding system where food feeder follows the path through a pre-determined distance and places the feed to the cattle by the side of the feed fence. They developed a prototype using Arduino circuit for the operation of feed mechanism with certain time space. A rail bogie is operated by a DC motor to feed the cattle at certain time space. Feed-to-gain, dressing percentage and USDA quality and yield grades were not affected by feeding frequency. This mechanism is mainly controlled by pulling mechanism by winding the rope around the motor operated shaft. Pratiksha Karn *et al*., (2019) designed and implemented an automatic cattle feeding system using Arduino Bluetooth controller. They controlled the motors to operate bidirectionally. They employed a sliding door driven by a DC motor to open and place the feed. They also incorporated an ultrasonic sensor to detect unnecessary objects. Additionally, they enabled a smartphone based wireless switching feature for manual intervention. They discovered that the advanced systems used a raspberry pi as the microcontroller for faster speed and processing. They reported that the developed robotic vehicle could track and distribute the feed along a specified path and distance

Automatic cleaning or washing system.

In today`s scenario farmers are having hard time in maintaining the cow shed to clean the cow dung they have to spend more time or they have to hire workers for more money. So in this paper we suggest a mechanism which is used to collect the cow dung and also used to clean the area. We use cow dung cleaning machine which runs under the power generated by solar. By using this process automatically human power will be saved.

Michael Krauß *et al*., (2016) measured the drinking and cleaning water use in a dairy cow barn. They installed thirty-eight water meters in a barn with 176 cows and two milking systems (an automatic milking system and a herringbone parlour). They logged their counts hourly over 806 days. The cows in the automatic milking system used 91.1 (SD 14.3) L drinking water per cow per day on average, while those in the herringbone parlour used 54.4 (SD 5.3) L per cow per day. The cows drank most of the water during the hours of (natural and artificial) light in the barn. They reviewed previously published regression functions of drinking water intake of the cows and developed a new regression function based on the ambient temperature and the milk yield (drinking water intake (L per cow per day) = −27.937 + 0.49 × mean temperature + 3.15 × milk yield (R2 = 0.67)). The cleaning water demand had a mean of 28.6 (SD 14.8) L per cow per day in the automatic milking system, and a mean of 33.8 (SD 14.1) L per cow per day in the herringbone parlour. These findings show that the total technical water use in the barn makes only a minor contribution to water use in dairy farming compared with the water use for feed production.

Vineeth Kumar MS *et al*., (2021) [56] designed and fabricated a Portable Animal Shed Cleaning Machine which is low cost, easy maintenance and eco-friendly, provides easy and effective cleaning of the floor. In this project the front has a blade that pushes the waste in and the belt drive carries it to the detachable collecting tank. And at the back brushes are provided with motor and with water supply at the back for easy cleaning. This work helps farmers for easy and quick cleaning in the animal shed and since electric motor is used for cleaning no cost for fuel consumption. They considered the comfort of the user and also the use of the motor is eco-friendly design and safety has been given utmost importance.

Laxmi Parajuli *et al*., (2021) [34] talked with dairy farmers in

Nepal, it became evident that animal waste collecting equipment was required. One of the main reasons for this requirement is labour scarcity, which is caused by employees' dislike of picking and collecting animal dung manually. They used a chain drive mechanism in this machine. The dung is collected with the help of picker/rubber pads that are welded to the chain, then dropped into the collector, and the process is repeated. The chain is coupled to a 12V battery-powered dc motor. This machine can collect dung at a rate of nearly 4.5 kg per minute with 98 per cent efficiency and easy to operate. The machine is cost-effective and saves time by reducing human labour. It can also be used as a stand-alone device in remote areas.

Vijaykumar L S *et al*., (2015) [57] designed a floor cleaning machine. This machine serves the basic needs of cleaning large and medium shed. In this machine the blade which is at the front will carry and lift the cow dung to the carrying tub which is placed back to the blade by manual lifting mechanism. And the motor fitted to brush through pulley by means of belt, which helps in cleaning the floor. The dry grass should be removed before using machine and Water tank must be placed at least 15 feet above the floor for the pressure. The water supply is arranged such a way that it should help in easy cleaning. Since electric motor is used for cleaning no cost for fuel consumption.

Luciana Bava *et al*., (2009) [35] observed the cleaning procedures of milking systems in 7 dairy cow farms in Lombardy and to find a relation between effectiveness of cleaning system and the bacterial quality of bulk tank milk, remaining washing water through milking equipment and teat cup surface. They used Lactocorder to monitor the cleaning procedures, which measured: duration, water temperature, turbulence, percentage of water in pipes, water conductivity of pre- and post-rinse and detergent phases. They found that the monitored farms had most of the cleaning parameters lower than the recommendations, especially maximum water temperature (42.1±9.9 °C) and percentage of water during detergent phase (76.1±13.9%). A maximum temperature of detergent phase <40°C resulted in a high Standard Plate Count (SPC), thermoduric bacteria and Coliform Count (CC) of bulk tank milk, SPC and CC of teat cup surface. They suggested that monitoring the efficiency of cleaning milking equipment with proper tools provide useful information about possible sources of contamination of bulk tank milk. Improving cleaning milking efficiency allow to improve milk quality.

Ankush Dharmik *et al*., (2022) [6] designed and fabricated the Solar Automatic Cow Dung Cleaner. They used a control system with the components like, Limit switches, DC motors, DC pumps, solenoid valves, and drag among the mechanical and electrical components. The machine's operation is based on the operator's manual push. This machine uses a blade to lift the waste, which is then collected in the tub. The front blade for lifting garbage is manually actuated by a lifting mechanism. The machine is built in such a way that the waste collection tub can be removed for unloading. The machine's structure is sturdy and robust to ensure the user's comfort. 4hrs time needed to charge the battery. It is a quick procedure that takes little time and there is no consumption of fuel since it is solar operated.

Atul Patil *et al*., (2021) [8] designed and developed solar operated automatic animal dung cleaner. Animal waste purifier suitable for scrapping animal waste in a passageway the waste that's in semisolid and it'll be collected in green manner with-out harming the animals and maintain the hygienic conditions. Skilled operator is needed for controlling for operation. To help farmers by reducing the difficulty of cleaning waste on the shed suggested the mechanism "sun powered automatic cow dung cleaning device for cowshed". These types of project can be mainly implement with in the dairy farming for quick and fast cleaning of the environment of farm and it will save water as well as human labour or human power.

Gurucharan M Shinde *et al*., (2017) [20] proposed automation in the process of cleaning the dairy farm with the press of a button. The main reason behind this concept is the cost of the labor that is required to maintain the hygiene and the cleanliness of the cow shed. The model consists of a pair of guide ways which is a primary load carrying member, the rack and pinion mechanism helps in the movement of machine apparatuses along the length of the scaled down frame and the electric DC motor is mounted with a gear on top which drives the machine along the rack. There are two support guide ways mounted to the bottom of the main frame machine. The movement along the length and height of the cow shed is considered as x axis and Y axis respectively. The brush assembly is made to move along the two guide ways with the help of a screw rod and gear drive mechanism. The screw rod set up is coupled to a controllable DC motor, where the motion of the motor can be controlled by the output of the limit switch. It has more advantages as compared to recent design as it helps in lifting cow dung with easy and quick cleaning and environmental friendly since fuel is not used, hence cost effective for farmers.

Other machines used in dairy industries

Emilie Mc Connachie *et al*., (2018) [42] studied the motivation of dairy cows to access an automated mechanical brush, a grooming resource that can be used in indoor cattle housing systems. They trained cows to push a weighted gate to access fresh feed (positive control), a mechanical brush or the same space without a brush (negative control). They increased the weight on the gate until all cows failed to open it. They used the Kaplan–Meier survival analysis to measure the weight each cow was willing to push to access each resource. Even though they used different methods to get data on motivation to access feed and the brush, the results were very similar; cows worked as hard for access to fresh feed and the brush (p ¼ 0.94) and less hard for access to the empty space (compared with fresh feed: p , 0.01; brush: p , 0.02). These results show that cows are highly motivated to access a mechanical brush and that it is an important resource for cows.

Serap Goncu *et al*., (2019) [51] pointed out some problems with technological grooming instruments. Grooming in cattle removed dirt, dust and parasites, increased skin blood circulation and muscles are massaged. Improper applications during the acclimatization period, the use of small and low-placed brushes that are not suitable for the size and structure of the cattle, malfunctions during the operation of the grooming brush and in the event of incorrect operation, the wounds occurring in different parts of the body can prevent the expected benefit from the use of the grooming brush. But many works continue on this subject to provide more efficient grooming instruments for cow comfort. And grooming is considered a potential indicator of positive welfare. The combination and integration of welfare instruments will ensure optimum wellbeing for dairy animals to maximize profitability. Use of welfare instruments combined with new technologies for information handling and integration to instruments give more effective results.

R. Mandel *et al*., (2013) [47] investigated the effect of distance from food, heat load, and an intrusive medical procedure (i.e., artificial insemination and transrectal pregnancy examination) on the resilience of brush usage. There is an availability of luxurious activity to cows on an increasing number of dairy farms is rubbing against an automated brush. The probability of using the brush decreased significantly when food was located far from the brush (mean = 0.53) compared with days when food was located near the brush (mean = 0.81). Brush usage also decreased at high temperature and humidity levels, with an average decrease of 0.062 brushing events for an increase of 1 temperature-humidity index unit (95% confidence interval = −0.93–0.030). In addition, a significant reduction of approximately 50% in brushing activity was observed on days of artificial insemination compared with the previous 3 d and the following 3 d. These findings show that brush usage is a low resilience activity that reduces under a range of conditions. It may thus have the potential to be used as an indicator of a range of health and welfare problems in cows.

Shigeru Ninomiya (2019) [52] studied the effect of animal self-grooming and welfare of fattening cattle. For Trial 1, they provided a brush to half of the animals. They recorded the animals' behaviour, carcass weight, and Viscera disease. Enrichment animals (E) performed more self-grooming and scratching of their body on the brush and pen structures than control animals © did (mean time budgets, 3.34% (SD = 2.48) in E and 0.89% (SD = 0.81) in C, GLMM, z value = 8.28, $p<$ 0.001). The number of animals with viscera disease detected after slaughter was lower in E than in C (E = 0, C = 4, a Fisher's exact probability test, p = 0.03). In Trial 2, they observed brush use behaviour continuously for 72 h. They found that the animals scratched different body parts on the brush. They concluded that providing a brush as environmental enrichment improves welfare by satisfying the motivation of fattening cattle to perform self-grooming.

Congcong Li *et al*., (2020) examined the behavioural response of dairy calves with artificial grooming treatment. They simulated the maternal licking by manually brushing right after the Holstein female calves were born and during their first week of life, called artificial grooming (AG). They compared the behaviour of these treated calves (AG, n = 17) with the calves without artificial grooming (Con, n = 16) during daily behavioural observation around evening milk feeding and in the open field test (OFT) and novel human test (NHT). They recorded the number of calves ingesting starter on day six. They observed that the AG calves were more active and performed more oral behaviour than the Con calves around evening milk feeding. The AG calves were also more active than the Con calves in the OFT and NHT. Moreover, the AG calves tended to be less fearful and had more human interactions than the Con calves in the NHT. There was a tendency for a higher percentage of AG calves ingesting starter on day 6. They suggested that artificial grooming during early life could increase the activity and the human affinity of female calves and it might promote their starter diet ingestion.

Kelebaone Tsamaase *et al*., (2020) [32] described a dip spraying system which can be used to spray dip mixture on livestock such cattle for control of parasites. They designed the system such a way that it can be used at remote locations where there is no extension of national electricity grid. They used solar power as the source of energy to drive electrical equipment. It is an automated and also it triggers the main power circuit to operate booster pump to spray dip mixture through the nozzles and detects the approaching animal. When the animal has passed through the system the spray stops operating. They showed that the system is effective and can be installed at places without any access to electric grid. Effectiveness of the system is such showing that it can spray the entire body of the animal at once within a limited period of time. The next stage would be to build the system at one of the farms and demonstrate it under real life environment.

Conclusion

This paper discusses the essential technologies, considerations and observations for the development of dairy mechanization which is important for dairy owners as there is a problem of labour availability, time saving and to improve a health condition of cattle. Mechanization is used by small dairy farmers for various purposes in handling farm activities, such as carrying and cutting forages, milking cows, cleaning shed, delivering goods and raw milk to milk collection service point. Mechanize the small dairy farmer's leads to a higher cattle-labour ratio which in turn it increases the productivity of farm labour. Mechanizing small farmer as well as farmer skill improvement in dairy farming practices that will saves labour is needed to help farmers scale up their farming when there is increases in wage rate. Procurement and maintenance of machinery in the early years of mechanization is required to help and encourage the farmer to mechanize their dairy farming. Innovation in marketing is equally important, lots of innovations have taken place recently, and these innovations have not percolated to the actual users.

These are some inspiring stories of mechanization in dairy farming in Marathwada region of Maharashtra.

1. NDDB's Vidarbha & Marathwada Dairy Development Project transforming lives: Chairman, NDDB. This project is working with the Government of Maharashtra to implement mechanization in dairy farming in drought-prone regions of Vidarbha and Marathwada. It has improved the income of more than 91,000 farmers by providing fair share of consumer price, setting up milk procurement infrastructure, providing quality cattle feed and mineral mixture, training farmers in silage making, and facilitating market linkages.
2. 'White Revolution' In Rural Maharashtra: Scripting success with dairy farming; salesman & a school dropout. This article features two young farmers who quit their jobs in Mumbai and returned to their native villages to do dairy farming. They have adopted mechanized milking systems, automatic cooling systems, and automatic water drinking systems, which have increased their milk yield and quality, reduced their labour cost, and enhanced their animal welfare and profitability.
3. Mr. Prakash Patil from Sangli district, has adopted a mechanized milking parlour, a biogas plant, a fodder chopper machine, and a fodder storage unit. He has increased his milk production from 40 litres to 300 litres per day and earned several awards for his innovations.
4. Mr. Rajendra Deshmukh from Latur district, has adopted a mechanized milking machine, a biogas plant, a fodder chopper machine, and a vermin compost unit. He has increased his milk production from 20 litres to 150 litres per day and also earned several awards for his innovations.
5. Mr. Prakash Kadam from Satara district, has adopted a mechanized milking machine, a biogas plant, a fodder chopper machine, and a solar water heater. He has

increased his milk production from 30 litres to 200 litres per day and earned several awards for his innovations.

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