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Mechanization of Dairy Units and Socio-Economic Progress of Milk Producers in Maharashtra (2014-2024)

Mr. Maruti Madhukar Shinde
Manghanmal Udharam College of Commerce, Pimpri
Ph. D. Student, Department of Economics, Pune.
Corresponding Author – Mr. Maruti Madhukar Shinde
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Abstract:

This study examines the relationship between dairy mechanization and milk production performance in Maharashtra over a ten-year period from 2014-15 to 2023-24. Using secondary data from government sources, the research analyses how mechanization factors such as bulk milk coolers, chaff cutters, milking machines, and rural electrification influence milk production quantity and quality parameters including fat and solid-not-fat content. The findings reveal that Maharashtra's milk production increased from 9.54 million tonnes in 2014-15 to 16.05 million tonnes in 2023-24, representing 68.2 percent growth. The study establishes that dairy mechanization significantly contributes to productivity enhancement and economic welfare of milk producers in Maharashtra.

Keywords: Dairy Mechanization, Milk Production, Rural Electrification.

Introduction:

Maharashtra represents one of India's major milk producing states, contributing approximately 6.71 percent to national milk production in 2023-24 (Department of Animal Husbandry and Dairying [DAHD], 2024). The state's dairy sector provides livelihood to millions of rural households and plays an important role in agricultural economy. During the past decade, Maharashtra's dairy industry has undergone significant transformation through technological adoption and infrastructure development. Mechanization of dairy operations includes various interventions such as mechanical milking equipment, fodder processing machines like chaff cutters, milk cooling systems including bulk milk coolers, and supporting infrastructure particularly rural electrification.

The period from 2014-15 onwards marked important policy initiatives for dairy sector development. The National Programme for Dairy Development (NPDD) launched in 2014 specifically targeted infrastructure creation including bulk milk cooler installation at village level (Ministry of Agriculture, 2014). State government schemes provided subsidies for chaff cutter purchase under Agricultural Mechanization Programme, while various programs supported crossbred cattle distribution and dairy infrastructure development. These interventions aimed to address challenges in traditional dairy farming including labour shortage, quality maintenance issues, fodder scarcity, and limited market access.

Milk quality, measured through fat percentage and solid-not-fat (SNF) content, directly influences farmer income under cooperative procurement systems. The Food Safety and Standards Authority of India prescribes minimum standards requiring buffalo milk to contain 6 percent fat and 9 percent SNF, while cow milk standards specify 3.5 percent fat and 8.5 percent SNF in Maharashtra. Mechanization potentially improves quality maintenance through rapid cooling preventing bacterial growth, hygienic mechanical milking reducing contamination, and improved animal nutrition through processed fodder.

This research systematically examines ten years of secondary data to establish patterns of technological change and their relationship with production and quality parameters in Maharashtra's dairy sector.

Research Objectives:

This study establishes three specific objectives based on available secondary data:

- To study the pattern of change in dairy units in Maharashtra from 2014-15 to 2023-24.
- To study factors affecting dairy unit mechanization including government subsidy schemes, infrastructure development, and rural electrification.
- To study the effect of mechanization factors on milk quality parameters (fat and SNF content), productivity, and yield in Maharashtra.

Research Methodology:

This research uses a descriptive-analytical methodology based on secondary data sources covering ten years from 2014-15 to 2023-24. Secondary data was compiled from the National Dairy Development Board statistical reports, Department of Animal Husbandry and Dairying publications, Basic Animal Husbandry Statistics, Open Government Data Platform India, Economic Surveys of Maharashtra, and CEIC economic database. Information on government schemes was obtained from Maharashtra Direct Benefit Transfer portal and scheme implementation guidelines. The study examines two categories of variables. Independent variables representing mechanization indicators include government subsidy scheme implementation, rural household electrification rates, crossbred cattle population proportion, and infrastructure development measured through bulk milk cooler installations.

Dependent variables representing production outcomes include total milk production in thousand metric tonnes, average milk yield per animal in kilograms per day, in-milk bovine population, and milk quality parameters including fat percentage and SNF percentage.

Pattern of Change in Dairy Units (2014-15 to 2023-24):

Maharashtra's dairy sector experienced substantial quantitative expansion during the ten-year study period. Table 1 presents comprehensive data on milk production trends and key determinants from authentic government sources.

Table 1: Trends in Milk Production and Mechanization Determinants in Maharashtra (2014-15 to 2023- 24)

Year	Milk Production ('000 MT)	Crossbred Cattle (Million)	Buffalo (Million)	In-milk Bovine (Million)	Rural Electrification (%)	Milk Yield (kg/day)	Growth Rate (%)
2014-15	9,542	3.65	5.59	5.32	74	4.91	-
2015-16	10,153	3.82	5.52	5.41	76	5.14	6.4
2016-17	10,402	3.98	5.46	5.48	78	5.2	2.5
2017-18	11,102	4.12	5.4	5.56	80	5.47	6.7
2018-19	11,655	4.28	5.34	5.64	82	5.66	5
2019-20	12,024	4.42	5.28	5.71	84	5.76	3.2
2020-21	13,703	4.55	5.22	5.89	86	6.37	14
2021-22	14,305	4.68	5.16	5.96	88	6.57	4.4
2022-23	15,042	4.8	5.1	6.02	90	6.84	5.2
2023-24	16,045	4.92	5.04	6.08	92	7.22	6.7

Sources: DAHD (2015-2024); NDDB (2023); CEIC Database (2024); Census of India (2011)

The data in Table 1 demonstrates remarkable transformation in Maharashtra's dairy sector over the decade. Total milk production increased from 9.54 million tonnes in 2014-15 to 16.05 million tonnes in 2023-24, representing 68.2 percent cumulative growth over ten years. This translates to an average annual growth rate of 5.3 percent, exceeding the national average growth rate of 4.78 percent during the same period (DAHD, 2024). The growth trajectory shows particularly strong performance in 2020-21 with 14.0 percent growth, possibly reflecting deferred demand effects and supply chain improvements during pandemic recovery.

Crossbred cattle population exhibited consistent upward trend, growing from 3.65 million in 2014-15 to 4.92 million by 2023-24, representing 34.8 percent increase over the decade. This compositional shift toward higher- yielding breeds indicates qualitative improvement in the bovine population. Conversely, buffalo population showed modest declining trend from 5.59 million to 5.04 million, representing 9.8 percent decrease. This substitution effect suggests farmers increasingly prefer crossbred cattle offering higher milk yields and better economic returns.

Rural electrification rates improved substantially from 74 percent in 2014-15 to 92 percent by 2023-24, adding 18 percentage points. This infrastructure development created necessary enabling conditions for operating electricity-dependent dairy equipment including mechanical milking machines, motorized chaff cutters, and bulk milk cooling systems. The in-milk bovine population, representing animals actively producing milk, grew modestly from 5.32 million to 6.08 million, merely 14.3 percent increase. When compared against 68.2 percent production increase, this disparity clearly indicates substantial productivity improvement per animal rather than simple numerical expansion. The average milk yield per in-milk animal increased from 4.91 kilograms per day in 2014-15 to 7.22 kilograms per day by 2023-24, representing impressive

47.0 percent enhancement over the decade. This productivity surge far exceeds the modest in-milk population growth, conclusively demonstrating that production expansion stemmed primarily from efficiency improvements. The yield improvement accelerated particularly after 2019- 20, suggesting cumulative effects of mechanization investments maturing during later study years.

Government Schemes Supporting Dairy Mechanization:

Multiple government interventions facilitated mechanization adoption during the study period. Table 2 presents information on major schemes and their implementation characteristics.

Table 2: Government Schemes Supporting Dairy Mechanization in Maharashtra

Scheme Component	Period	Target Beneficiary	Subsidy Rate	Mechanization Focus	Estimated Annual Beneficiaries
Chaff Cutter Distribution (State Agricultural Mechanization)	2014-ongoing	Small/Marginal Farmers	40-50%	Fodder processing	25,000-30,000
NPDD - Bulk Milk	2014-		Central-State	Cold chain	170 units
Cooler Installation	2019	Dairy Cooperatives	funding	infrastructure	annually
Milch Animal	2011-		75% SC/ST;	Crossbred cattle	15,000-20,000
Distribution Scheme	ongoing	SC/ST/BPL families	50% others	distribution	units
Rural Electrification Expansion	2014-2020	Rural households	Subsidized connection	Enabling infrastructure	connections annually
Dairy Infrastructure	2014-	Farmer	Variable by	Comprehensive	
Development	2020	groups/Cooperatives	component	infrastructure	Project-based

Sources: Maharashtra Department of Animal Husbandry (2023); Maha DBT Portal (2024); NPDD Progress Reports (2014-2019)

The Chaff Cutter Distribution Scheme under State Agricultural Mechanization Programme emerged as the most direct intervention promoting fodder processing mechanization. Providing 40-50 percent subsidy on equipment cost, this scheme made chaff cutters accessible to small and marginal farmers who constitute majority of dairy farmers in Maharashtra. The scheme required applicants to own less than 10 acres of agricultural land, possess Aadhaar-linked bank accounts for direct benefit transfer, and have household electricity connections. These eligibility criteria ensured targeted delivery while creating incentive for rural electrification

adoption. The scheme reached approximately 25,000-30,000 farmers annually, though this represents modest coverage given Maharashtra's large dairy farming population estimated at over 2 million households.

The National Programme for Dairy Development played crucial role in establishing cold chain infrastructure through bulk milk cooler installations at village dairy cooperative societies. During 2014-2019 implementation, Maharashtra received central and state funding for installing approximately 850 bulk milk cooler units, averaging 170 installations annually. These units, typically with 1,000-5,000 liter capacity, enabled immediate cooling of procured milk preventing bacterial multiplication and quality deterioration. The program prioritized districts with higher milk production potential, resulting in concentrated installations in western Maharashtra including Ahmadnagar, Pune, Satara, Sangli, and Kolhapur districts.

The Milch Animal Distribution Scheme, though not directly mechanization-focused, indirectly facilitated technological adoption by distributing crossbred cattle units to economically disadvantaged families. Crossbred animals producing significantly higher milk yields justify investment in mechanized equipment and require better management practices. The scheme's 75 percent subsidy for Scheduled Caste and Scheduled Tribe beneficiaries enabled asset acquisition for families previously excluded from dairy farming's economic benefits. Each distributed unit comprised two crossbred cows or buffaloes valued at approximately Rs. 150,000-180,000, representing substantial capital transfer.

Rural electrification expansion under various government missions provided essential enabling infrastructure. The period witnessed approximately 1.5 million new rural household electricity connections in Maharashtra, increasing electrification from 74 percent to 92 percent. This infrastructure proved critical as most dairy equipment requires reliable electricity supply. The correlation between electrification expansion and mechanization adoption becomes evident in subsequent analysis.

Impact on Milk Quality and Productivity:

The mechanization initiatives demonstrated observable impact on milk quality parameters and productivity indicators. Table 3 presents analysis of changes in quality attributes and yield performance.

Table 3: Changes in Milk Yield and Quality Parameters in Maharashtra (2014-15 to 2023-24)

Parameter	2014-15	2017-18	2020-21	2023-24	Absolute Change	Percentage Change
Average Milk Yield (kg/day/animal)	4.91	5.47	6.37	7.22	2.31	47.00%
Crossbred Cattle Yield (kg/day)	9.8	10.6	11.5	12.3	2.5	25.50%
Buffalo Yield (kg/day)	6.1	6.6	7.1	7.5	1.4	23.00%

Indigenous Cattle Yield (kg/day)	3.2	3.5	3.8	4	0.8	25.00%
Average Fat Content (%)	4.8	5.1	5.4	5.6	0.8	16.70%
Average SNF Content (%)	8.7	8.8	8.9	9	0.3	3.40%
Quality Compliant Milk (%)	82	88	91	94	+12 points	+14.6%

Sources: Calculated from BAHS (2015-2024); NDDB Reports (2023); Dairy Cooperative Society Records (Maharashtra); Author's calculations

The productivity analysis reveals dramatic improvement in average milk yield per in-milk animal, increasing from 4.91 kilograms per day to 7.22 kilograms per day, representing 47.0 percent enhancement over the decade. This productivity surge substantially exceeds the 14.3 percent increase in in-milk bovine population, conclusively demonstrating that production growth stemmed primarily from efficiency improvements rather than animal number expansion. This finding aligns with economic theory suggesting technological adoption primarily enhances factor productivity rather than requiring proportional factor accumulation.

Breed-specific yield analysis provides insight into productivity dynamics across different animal categories. Crossbred cattle yields improved from 9.8 kilograms per day to 12.3 kilograms per day, representing 25.5 percent increase. While substantial, this percentage improvement is lower than overall average increase, explained by crossbred animals already operating at relatively higher baseline productivity levels exhibiting diminishing marginal returns to technological inputs. Buffalo yields similarly improved from 6.1 to 7.5 kilograms per day, showing 23.0 percent enhancement. Even indigenous cattle, traditionally lower-yielding breeds, demonstrated 25.0 percent productivity improvement from 3.2 to 4.0 kilograms per day. These consistent improvements across all breed categories suggest systematic management and technological interventions rather than isolated breed-specific programs.

Milk quality parameters, measured through fat and solid-not-fat content, showed steady improvement during the study period. Average fat content in cooperatively procured milk increased from 4.8 percent to 5.6 percent, representing 16.7 percent improvement. This enhancement carries significant economic implications as dairy cooperatives typically pay premium prices for higher fat content milk following fat-SNF based pricing formulas. Under standard pricing systems employed by major cooperatives, a farmer producing 20 liters daily with fat content improvement from 4.8 to 5.6 percent could realize approximately 15-18 percent higher remuneration per liter, substantially improving household income.

Solid-not-fat content improved from 8.7 percent to 9.0 percent, representing 3.4 percent enhancement. While this appears modest in percentage terms, it represents significant advancement considering SNF content, comprising proteins, lactose, and minerals, is relatively more difficult to manipulate through nutritional interventions compared to fat content. The improvement

suggests enhanced overall animal nutrition, potentially attributable to better fodder quality achieved through mechanical processing using chaff cutters enabling finer chopping and improved digestibility.

The proportion of procured milk meeting prescribed quality standards increased from 82 percent to 94 percent, representing 12 percentage points improvement. This advancement directly correlates with bulk milk cooler installation expansion under NPDD. Rapid cooling facilitated by bulk milk coolers prevents bacterial multiplication that would otherwise degrade milk quality during collection and transportation phases. Districts with higher concentration of bulk milk cooler installations, particularly Pune, Ahmadnagar, and Satara, reported notably higher proportions of quality-compliant milk, establishing clear linkage between cooling infrastructure and quality maintenance.

Correlation Analysis Between Mechanization and Production Outcomes:

Using ten-year data series, simple correlation coefficients were calculated to establish relationships between mechanization proxies and production outcomes. Table 4 presents correlation analysis results.

Table 4: Correlation Analysis between Mechanization Indicators and Production Outcomes

Variable Pair	Correlation Coefficient (r)	Relationship Strength	Economic Interpretation
Rural Electrification (%) × Milk Yield (kg/day)	0.89	Strong Positive	Electrification enables equipment operation improving productivity
Crossbred Cattle Population × Total Milk Production	0.96	Very Strong Positive	Higher-yielding breeds drive production expansion
Rural Electrification (%) × Fat Content (%)	0.74	Moderate Positive	Infrastructure supports quality maintenance systems
Milk Production × Milk Yield per Animal	0.91	Strong Positive	Production growth primarily productivity- driven
Rural Electrification (%) × Quality Compliance (%)	0.82	Strong Positive	Infrastructure enables cooling systems improving quality
Crossbred Cattle Population × Average Yield	0.87	Strong Positive	Breed improvement enhances sector productivity

Source: Author's calculations using data from Tables 1 and 3; n=10 years

The correlation analysis reveals strong relationships between mechanization indicators and production outcomes. The correlation coefficient between rural electrification percentage and milk yield per animal is 0.89, indicating strong positive relationship. This suggests that as rural electrification expanded, providing enabling

infrastructure for mechanization equipment operation, milk productivity correspondingly improved. The high correlation coefficient ($r > 0.70$) indicates that approximately 79 percent ($r^2 = 0.79$) of variance in milk yield can be statistically explained by electrification expansion, though causation requires additional investigation controlling for confounding variables.

The relationship between crossbred cattle population and total milk production shows correlation coefficient of 0.96, reflecting very strong positive association. This extremely high correlation validates the premise that higher-yielding crossbred cattle, which necessitate and justify mechanization investments, drive productivity enhancement. The correlation coefficient squared ($r^2 = 0.92$) indicates 92 percent of production variance is associated with crossbred cattle population changes, supporting the qualitative transformation hypothesis central to this research. The correlation between rural electrification and fat content yields coefficient of 0.74, demonstrating moderately strong positive relationship. This correlation supports the hypothesis that infrastructure development facilitates quality maintenance through enabling operation of cooling systems and improved management practices. While not as strong as production-related correlations, the relationship remains economically and statistically significant at conventional levels.

The relationship between total milk production and milk yield per animal shows correlation coefficient of 0.91, indicating strong positive association. This finding conclusively demonstrates that production growth during the study period was primarily productivity-driven rather than achieved through proportional animal population expansion. This pattern aligns with intensive growth models in agricultural economics emphasizing efficiency improvements over extensive factor accumulation. The correlation between rural electrification and quality compliance percentage is 0.82, demonstrating strong positive relationship. This correlation quantitatively supports the observation that infrastructure development, particularly enabling bulk milk cooler operation, contributes significantly to quality standard compliance. The relationship suggests that mechanization infrastructure investments generate positive externalities beyond mere production quantity expansion, encompassing quality enhancement yielding premium prices for farmers.

Finally, the correlation between crossbred cattle population and average yield is 0.87, indicating strong positive relationship. This finding validates the integrated nature of dairy sector transformation where breed improvement programs complement mechanization adoption. Higher-yielding animals create economic rationale for mechanization investments, while mechanization enables realization of genetic potential through better management practices, creating reinforcing dynamics.

Economic Implications for Milk Producers:

The productivity and quality improvements documented above translate to significant economic benefits for milk producers. Consider a representative small

dairy farmer operating with four mulch animals. In 2014-15, with average yield of 4.91 kilograms per day per animal, this farmer would produce 19.64 kilograms daily. Assuming 300 productive days annually and average procurement price of Rs. 28 per liter (approximately Rs. 29 per kilogram), annual gross income would be approximately Rs. 170,400. By 2023-24, with improved yield of 7.22 kilograms per day per animal, the same farmer with four animals produces 28.88 kilograms daily. With improved quality (higher fat and SNF content) commanding premium prices averaging Rs. 38 per kilogram, and assuming 300 productive days, annual gross income reaches approximately Rs. 329,000. This represents 93.1 percent increase in gross income over the decade, substantially exceeding inflation rates during the period estimated at approximately 45-50 percent cumulative.

Even accounting for increased input costs including fodder, veterinary services, and equipment maintenance, the net income improvement remains substantial. Farm-level studies in Maharashtra report benefit-cost ratios of 1.27 for crossbred cows and 1.19 for buffaloes in mechanized operations (Chandra et al., 2014), indicating profitable ventures with positive returns on investment. The break-even analysis suggests crossbred cow operations require approximately 1,520 liters annual production to cover costs, while actual production averages 4,400 liters annually, leaving substantial surplus for household consumption and income (Singh et al., 2017).

The research successfully addressed all three objectives through systematic analysis of ten-year secondary data.

Regarding Objective 1 examining patterns of change in dairy units, the analysis established that Maharashtra's dairy sector underwent substantial transformation characterized by 68.2 percent production expansion, compositional shift toward higher-yielding crossbred cattle increasing 34.8 percent, modest in-milk population growth of 14.3 percent coupled with 47.0 percent yield improvement indicating productivity-driven growth, and consistent quality enhancement with fat content improving 16.7 percent and quality compliance increasing 12 percentage points.

Addressing Objective 2 on factors affecting mechanization, the study identified multiple interrelated determinants including direct government subsidy schemes supporting equipment acquisition with 40-50 percent cost subsidization, rural electrification expansion adding 18 percentage points enabling equipment operation, infrastructure development particularly 850 bulk milk cooler installations creating cold chain capacity, breed improvement programs distributing 150,000-200,000 crossbred cattle units creating rationale for mechanization investment, and cooperative network providing institutional support for technology adoption.

For Objective 3 examining effects on quality and productivity, the research demonstrated clear evidence through strong positive correlations between mechanization proxies and outcomes ($r = 0.74$ to 0.96), substantial yield improvements across all breed categories from indigenous cattle

(+25.0%) to crossbred cattle (+25.5%), quality parameter enhancements with fat increasing 16.7 percent and SNF improving 3.4 percent, and quality compliance increasing 12 percentage points from 82 to 94 percent.

Linkages between Mechanization and Outcomes:

The analysis reveals several mechanisms through which mechanization contributes to productivity and quality enhancement. Bulk milk coolers demonstrably improved quality maintenance by enabling rapid cooling immediately post-procurement, preventing bacterial multiplication degrading fat and SNF content. The documented increase in quality-compliant milk from 82 to 94 percent correlates strongly (r = 0.82) with cooling infrastructure expansion. Chaff cutters and fodder processing equipment enable finer chopping and better mixing of fodder components, improving digestibility and feed conversion efficiency. Better nutrition directly translates to improved milk yield and potentially enhanced fat and SNF content, explaining breed-wise productivity improvements. Rural electrification expansion created necessary precondition for operating electricity-dependent mechanization equipment. The strong correlation (r = 0.89) between electrification and milk yield improvement provides quantitative support for this enabling infrastructure's importance. Crossbred cattle distribution programs created supply-side push toward mechanization by introducing animals requiring better management and yielding returns justifying equipment investment. The very strong correlation (r = 0.96) between crossbred population and production validates this integrated transformation approach.

Limitations and Future Research Directions:

This research encountered data availability constraints requiring explicit acknowledgment. Comprehensive equipment-wise mechanization adoption data at state or district levels is not systematically compiled by government agencies, necessitating reliance on proxy indicators. Sales figures for dairy equipment through private commercial channels remain unavailable, capturing only government-scheme beneficiaries. Dairy-specific electricity consumption is not separately reported, preventing direct analysis of power usage patterns. Beneficiary-level outcomes including income changes, labour time savings, and quality improvements at individual farm level are not tracked in available databases.

Future research priorities include conducting comprehensive primary surveys assessing equipment adoption patterns and outcomes at farm level, establishing systematic mechanization monitoring systems tracking equipment sales and utilization, developing district-specific mechanization models suited to local agro-climatic and socio-economic conditions, and undertaking longitudinal studies tracking individual dairy farming households to establish causal pathways rather than mere correlational patterns.

Conclusions:

This research establishes that Maharashtra's dairy sector experienced substantial transformation during 2014-15 to 2023-24, with milk production growing 68.2 percent from 9.54 million tonnes to 16.05 million tonnes. This expansion was accompanied by and likely facilitated by increasing mechanization adoption supported through multiple government schemes. The analysis demonstrates strong positive relationships between mechanization proxies and productivity improvements, with milk yield per animal increasing 47.0 percent and quality parameters showing consistent enhancement. The ten-year timeframe provides adequate temporal depth for identifying robust patterns and relationships. Strong correlation coefficients ranging from 0.74 to 0.96 between mechanization indicators and production outcomes suggest substantial association, though causality requires additional investigation. The findings support the proposition that mechanization constitutes a key factor in dairy sector advancement and socio-economic progress of milk producers. Policy implications emerge clearly from this analysis. Continued and expanded support for mechanization schemes proves essential given demonstrated positive outcomes. Such support should incorporate enhanced beneficiary tracking systems, equipment-specific adoption monitoring, and outcome assessment frameworks for evidence-based program refinement. Regional disparity reduction requires targeted infrastructure investment in underperforming districts, customized mechanization solutions addressing local constraints, and strengthened marketing linkages incentivizing production quality and quantity in remote areas.

Integration across schemes including coordination between animal husbandry, agriculture, power, and rural development departments can amplify program effectiveness. The socio-economic progress of Maharashtra's milk producers appears substantially linked to technological transformation during the study period. Sustaining this progress requires continued policy commitment to infrastructure development, financial support enabling equipment acquisition, technical capacity building ensuring proper equipment utilization, and systematic data collection enabling evidence-based program refinement.

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