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Review Article

A Comparative Analysis of Economics of Private and Cooperative Dairy System in Haryana

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Abstract: This study conducts a comparative economic analysis of cooperative and private dairy systems in Haryana, India. Using empirical field data, financial performance indicators, and gender-based productivity evaluations, it identifies critical operational differences between cooperative structures governed by the Haryana Dairy Development Cooperative Federation (HDDCF) and market-oriented private dairy enterprises. Cooperatives, emphasizing transparency and inclusive growth, struggle with higher procurement and processing costs, resulting in lower profitability compared to private processors who benefit from greater operational efficiency, flexible pricing, and quicker payment cycles. Additionally, gender-disaggregated analyses reveal significant disparities in resource access and productivity between male and female cooperative members. Despite institutional support and extensive service outreach, cooperative dairies face challenges in sustainability and profitability, whereas private dairies lack comprehensive farmer support mechanisms but offer higher immediate returns to producers. The findings suggest policy interventions focused on enhancing cooperative efficiency, improving gender equity, and integrating best practices from both cooperative and private models to ensure balanced sectoral growth.

Keywords: Dairy economics, Cooperative dairies, Private dairies, Haryana, Gender analysis.

1. INTRODUCTION

India holds the distinction of being the world's largest milk producer, contributing a significant 24% of global milk output as of 2022. Within this national framework, Haryana emerges as a critical player, with its annual milk production surpassing 8.25 million metric tonnes during 2018–2019 (Sumit Mahajan *et al*., 2019). The dairy sector here is not just an economic pillar-contributing roughly 25% to the state's agricultural GDP-but also a lifeline for rural communities, particularly those with limited landholdings (Singh *et al*., 2021). The industry is structured around two fundamentally distinct models: the cooperative system, rooted in collective farmer ownership, and the private enterprise model, driven by market efficiency. These systems differ sharply in their operational frameworks, pricing mechanisms, and institutional support structures, creating divergent outcomes for stakeholders.

The cooperative dairy model in Haryana is orchestrated by the HDDCF, which, as of 2009, integrated 6,000 Dairy Cooperative Societies (DCSs) and six district-level milk unions under the Anand Pattern's three-tier hierarchy (Yadav & Grover, 2009). This system processes a staggering 675,000 litres of milk daily, primarily distributed under the federation's flagship brand, 'Vita'. At the village level, procurement relies on electronic fat-testing equipment, with results disclosed immediately to producers-a transparency measure that ensures fair fat-based pricing (Yadav & Grover, 2009). Payments to farmers follow cooperative norms, typically settled within 10 days. However, procurement costs reveal regional disparities: ₹1.67 per litre in HDDCF's Eastern Zone compared to ₹1.83 in the Western Zone, where transportation alone consumes 54.5% of expenditures (Singh *et al*., 2021).

In contrast, the private dairy sector-comprising multinational corporations and regional processors-operates with markedly different dynamics. These entities often outbid cooperatives in procurement prices, leveraging advantages like direct consumer sales, diversified product portfolios, and flexible supply chains. A comparative study from Uttarakhand highlighted that private producers achieved higher net returns due to access to four distinct marketing channels (versus cooperatives' single-channel system), premium pricing, and faster payment systems (Chaudhary *et al*., 2019). Yet, private dairies face their own constraints: limited geographic penetration and weaker mechanisms for farmer integration, which restrict their ability to replicate the cooperative system's grassroots reach.

Value-addition economics further accentuate the divide between the two models. In HDDCF processing plants, profit margins vary widely by product: 23.76% for dahi (yogurt), 11.88% for ghee (clarified butter), and 15.21% for double-toned milk. Paneer (cottage cheese) production, however, lags with a 7.76% margin and a high unit cost of ₹16.05/kg, signaling inefficiencies in cooperative-scale operations (Singh *et al*., 2021). Private dairies, benefiting from larger processing capacities, often achieve lower per-unit costs and more competitive retail pricing. However, comprehensive cost-margin analyses for private units in Haryana remain scarce, leaving gaps in comparative assessments.

Gender dynamics add another layer of complexity. A stratified survey of 200 cooperative members (2010–2011) across Hisar and Mahendragarh districts revealed that men owned 3–5 cattle on average, generating 13.1 litres/day in milk sales, while women managed just 2 cattle, producing 10 litres/day (Yadav & Grover, 2013). Both groups reported moderate profitability and high occupational satisfaction, but women disproportionately faced structural barriers: limited access to veterinary care, informational asymmetry, and weaker bargaining power in markets (Deepti & Beena Yadav, 2007). These findings underscore the necessity of gender-disaggregated data in policy evaluations to ensure equitable development.

Despite its institutional resilience, the HDDCF faces systemic challenges. Research by Mahajan *et al*. (2019) notes a decline in average milk procurement per DCS, poor loan recovery rates, and deteriorating financial health (Sumit Mahajan *et al*., 2019). Meanwhile, private players-despite operational efficiency-often fail to institutionalize producer support services, leading to disparities in veterinary outreach, feed accessibility, and training programs (Kumar *et al*., 2012). This duality highlights a critical policy dilemma: cooperatives prioritize inclusivity but struggle with sustainability, while private firms excel in efficiency but neglect holistic farmer development.

This review rigorously examines the economic architectures, governance models, and on-ground impacts of Haryana's cooperative and private dairy systems. By synthesizing empirical field data, gender-based analyses, and financial performance metrics, it aims to provide a foundation for evidence-driven reforms-ensuring the sector's growth benefits all stakeholders, from smallholder farmers to large-scale processors.

2. The Dairy Sector in Haryana: An Overview

The dairy sector in Haryana operates under a dual structure consisting of state-led cooperatives working alongside market-driven private enterprises. This hybrid institutional model emerged from a series of policy reforms initiated in the post-1970s period and subsequently expanded under flagship national programs including Operation Flood. Current institutional data shows that as of 2019, the state had successfully established 6,249 registered DCSs complemented by 6 fully functional district milk unions, all systematically integrated under the umbrella of the HDDCF (Sumit Mahajan *et al*., 2019).

The HDDCF, which was formally constituted in 1977, currently procures approximately 675,000 litres of milk per day through its extensive cooperative procurement network (Yadav & Grover, 2009). The federation's procurement system utilizes automated fat testing technologies while maintaining fully transparent, quality-based payment mechanisms. The cooperative's diversified product portfolio - marketed under the well-known Vita brand - encompasses fluid milk, paneer, ghee, curd, lassi, and various traditional milk-based sweets. When examining comparative procurement figures, cooperatives demonstrate lower average price volatility relative to private sector counterparts; however, they face persistent constraints in scalability due to limited access to private capital investments and reduced market agility (SINGH).

By contrast, private dairy processors, including both formal registered enterprises and informal local units, have expanded aggressively throughout the last two decades. A detailed 2018–2019 study conducted in Karnal district documented that informal private dairy units typically operated at significantly lower per-unit production costs while achieving impressive profit margins of 53.0% for dahi and 12.75% for ghee production, advantages primarily attributable to their vertical integration strategies and lean distribution models (Thakur & Dixit, 2020). Notably, these private units remain largely outside formal cooperative frameworks and often operate unregulated by food safety agencies, which introduces considerable variability in both consumer quality assurance and regulatory compliance outcomes.

Institutional support mechanisms for cooperative dairying remain firmly anchored in combined state and central government programs. These include the National Dairy Plan Phase I, Rashtriya Gokul Mission, and Dairy

Entrepreneurship Development Scheme, all of which provide critical subsidies for breeding improvements, veterinary services, and infrastructure expansion. Cooperative-linked extension programs have demonstrated quantifiable success: in a comprehensive 2009 study, data showed that 67.12% of surveyed cooperative members had adopted standardized veterinary health care protocols, while 80.91% consistently adhered to improved feeding practices (Singh *et al*., 2010).

The cooperative system also incorporates targeted service delivery initiatives specifically designed for women participants. In a detailed 2009–2010 evaluation of four Women Dairy Cooperatives (WDCs) in Haryana, research revealed that while 58% of female beneficiaries demonstrated awareness of training programs covering fodder production and basic animal health, less than 50% reported any knowledge of available veterinary subsidies or credit-linked purchase schemes (Yadav & Dahiya, 2009). This significant disparity clearly indicates persistent gaps in cooperative communication strategies and underscores the growing need for implementing digital platforms or decentralized extension models to improve outreach.

The current stakeholder landscape remains concentrated yet increasingly competitive. HDDCF's Vita brand continues to service the bulk of state-level retail and institutional bulk supply markets, while Punjab's MILKFED (marketing under the Verka brand) operates under a parallel cooperative model and contributes to intensifying cross-border brand competition (SINGH). Meanwhile, Gujarat's Amul, operating through the Gujarat Cooperative Milk Marketing Federation (GCMMF), has successfully established a dominant pan-India presence, with steadily growing operations in Haryana through direct procurement systems and dedicated distribution infrastructure. Private sector players including multinational corporations like Nestlé, domestic giants like Mother Dairy, and numerous smaller urban-centric processors have progressively fragmented the market through differentiated pricing strategies, accelerated payment cycles, and selective product innovation approaches.

While these private dairies typically bypass traditional cooperative-level veterinary or extension services, they have consistently demonstrated superior logistics efficiency and significantly better cold chain penetration rates (Chaudhary *et al*., 2019). Despite institutional intent, cooperative milk procurement has shown signs of decline in operational intensity. Between 2010 and 2018, HDDCF reported a drop in average milk procurement per functional DCS, alongside reduced loan repayment ratios and increasing dependency on state subsidies (Sumit Mahajan *et al*., 2019). This trend correlates with private-sector encroachment and producer migration toward faster-remunerating channels.

3. Comparative Institutional Framework in Haryana

The dairy sector in Haryana is governed by two distinct institutional frameworks: cooperatives under the HDDCF, and decentralized private enterprises. The cooperative system operates a legally mandated three-tier structure comprising primary DCSs, district unions, and the state federation. As of 2009, HDDCF included 4,650 functional DCSs and six district unions, with total milk procurement averaging 675,000 litres per day (Yadav & Grover, 2009). Procurement is standardized through automated fat testing, with price differentials based on quality, and democratic governance is exercised via elected committees at the DCS and union levels (Yadav & Grover, 2010).

By contrast, private processors in Haryana follow a vertically integrated, non-democratic structure, typically overseen by owners or executive managers without any producer participation. A 2020 study in Karnal found that informal processors, operating with minimal administrative overhead, achieved profit margins of 53% on dahi and 12.75% on ghee, despite offering no veterinary services or producer support (Thakur & Dixit, 2020). This operational efficiency comes at the cost of farmer welfare safeguards, creating a clear trade-off between profitability and producer protection.

Cooperative governance offers formal participation channels but often lacks performance accountability mechanisms. A 10-year comparative analysis (2001-2011) of DAIRYFED (Haryana) and MILKFED (Punjab) revealed MILKFED's superior return on equity (18.3% vs 12.1%) and inventory turnover ratio (6.5 vs 4.2), while DAIRYFED showed concerning deficits in current ratio (1.2 vs 1.8) and debt-to-equity metrics (SINGH). Member satisfaction remains problematic - only 33% of cooperative producers reported satisfaction with transparency and complaint resolution systems (Nishi & Kumar, 2011).

Private-sector participants reported higher satisfaction on pricing (78% satisfied vs 42% in cooperatives) and payment timeliness (83% vs 51%), but lacked access to institutional services like extension programs (0% access vs 67% in cooperatives) or subsidized veterinary care (Raj *et al*., 2020). Gender disparities persist in both systems: male members typically managed 3-5 cattle yielding 13.1 litres/day, while female members averaged just 2 animals producing 10 litres/day. Women also faced 42% lower participation in governance meetings and 35% less training access (Yadav & Grover, 2013).

4. Economics of Milk Production in Haryana

The economics of milk production in Haryana show clear patterns across different breeds and farm sizes, with feed and fodder consistently emerging as the largest cost component. Detailed analysis of 120 dairy households reveals these inputs account for 69.1% of variable costs for buffalo, slightly less at 66.3% for crossbred cows, and 67.8% for indigenous cattle, while labor constitutes 17.3-19.2% and combined veterinary/mineral/depreciation costs remain below 10% (Mohapatra *et al*., 2021). When examining per-liter costs, buffalo milk production proves most expensive at ₹40.35, compared to ₹32.48 for crossbred and ₹31.88 for indigenous varieties, with corresponding gross returns of ₹46.75, ₹42.00, and ₹38.60 respectively - showing buffalo operations yield higher absolute returns despite greater input costs.

Scale advantages become particularly evident when comparing small and large commercial operations. Farms maintaining more than 10 crossbred cattle achieve significantly lower per-liter costs of ₹9.49 compared to ₹10.68 on smaller holdings, while buffalo operations show a similar trend ranging from ₹14.96 to ₹16.19, demonstrating how fixed cost dispersion and higher per-animal yields benefit larger producers (Sahu *et al*., 2012). This scale efficiency is further confirmed by Total Factor Productivity (TFP) measurements in Sirsa district, where large herds score 0.2202 and crossbred animals reach 0.2346, with a strong 0.62 correlation to farm mechanization levels (Lal & Chandel, 2016). Additional evidence comes from cost elasticity analyses in Sirsa and Hisar, quantifying a consistent 5.2% unit cost reduction for each ascending production quintile (Lal & Chandel, 2016).

Moving along the value chain, milk procurement and processing introduce substantial additional costs. Cooperative plants report average procurement expenses of ₹1.67 per liter in eastern Haryana rising to ₹1.83 in the western zone, primarily driven by transport (54.57%), chilling (23.92%), and collection (17.12%) costs (Singh *et al*., 2021). These proportions hold true in facility-specific audits, with a Sirsa plant showing 43.72% for transport, 21.9% for chilling, and 26.1% for procurement logistics (Doni & Chauhan, 2019). Value-added processing creates divergent margins - dahi yields 23.76%, ghee 11.88%, and paneer just 7.76% relative to base procurement costs (Singh *et al*., 2021), highlighting how product mix significantly impacts plant profitability.

Regional and operational differences further complicate the economic picture. In Rewari district, annual maintenance reaches ₹30,311 per buffalo (net return ₹29,790) versus ₹25,655 per cow (return ₹21,198) (Kumar *et al*., 2015), while large herds universally show 18-22% lower unit costs through process standardization. Adoption rates for improved practices vary dramatically - while 86% implement better hygiene and 74% enhanced nutrition, only 41% adopt veterinary improvements and 38% upgrade housing (Loura *et al*., 2021), suggesting untapped potential for efficiency gains.

Technology adoption demonstrates measurable impacts on productivity. Farmers accessing microfinance achieve 6.13 daily liters per buffalo versus 5.85 in control groups, alongside 12% better feed conversion ratios (Feroze *et al*., 2011). Production inefficiencies correlate strongly with reproductive cycle delays (β=0.38) and fodder shortages (β=0.42) in non-financed operations (Mohapatra *et al*., 2021). Environmental costs add another dimension, with smallholder buffalo milk production emitting 3.54kg CO_2/liter compared to 4.53kg in organized farms, though interestingly this shows no direct correlation to economic costs (Pordhiy & Gautam, 2023).

The breed performance hierarchy remains consistent across studies: crossbred cows deliver the most favorable economics with optimized costs of ₹28.12 and net returns of ₹14.22 per liter; buffalo follow with higher costs (₹36.44) but respectable returns (₹9.85); while indigenous cows trail with the poorest metrics (₹32.18 cost, ₹6.72 return) (Lal & Chandel, 2016; Mohapatra *et al*., 2021; Sahu *et al*., 2012). Infrastructure efficiency compounds these differences, showing 15-18% cost variations between centralized and decentralized procurement chains, particularly in fragmented chilling networks (Doni & Chauhan, 2019; Singh *et al*., 2021).

5. Milk Pricing and Farmer Remuneration in Haryana

Milk procurement pricing in Haryana follows fundamentally different systems between cooperatives and private operators, creating distinct economic outcomes for producers. The cooperative system under HDDCF employs rigorous quality-based valuation, using electronic milk analyzers to measure fat and SNF (solids-not-fat) content at collection points, which directly determines payments. During 2021, base prices per liter showed regional variation from ₹1.67 in eastern zones to ₹1.83 in western areas, with transport costs consuming 54.57% of downstream processing expenses (Singh *et al*., 2021). Private dairy firms take a markedly different approach, implementing non-standardized flat rates that typically exceed cooperative prices by ₹2.00 to ₹3.50 per liter, particularly during lean periods and festival seasons when demand peaks (Mohapatra *et al*., 2021; Sahu *et al*., 2012). This price divergence stems from structural differences - cooperative rates are set by district union boards with transparent quality metrics, while private firms use internal mark*et al*gorithms that disregard milk composition.

Payment systems reveal another layer of contrast between the sectors. Cooperatives maintain structured payment cycles of 8-12 days per batch through DCSs linked to Bulk Milk Cooler Units (BMCUs), with 41% of active DCSs

implementing fully digitized fat-analyzer-linked billing by 2021 (Loura *et al*., 2021). Evidence from Gujarat's Sabarkantha district, which uses similar BMCU systems, shows these digital approaches reduce payment delays by 43% compared to manual systems while boosting producer trust in weight and fat testing accuracy by 31% (Gurjar *et al*., 2022). Haryana's cooperatives further incentivize producers through bonus programs, with 28% of DCSs distributing quarterly payments ranging from ₹0.50 to ₹1.25 per liter based on union-level surpluses and meeting strict volume/quality thresholds (Ghalawat *et al*., 2022). Private sector operations present a trade-off - while 100% of sampled producers receive immediate payment, none benefit from volume-based or quality-linked bonuses, and 74% remain unaware of how their prices are determined (Gautam *et al*., 2015; Loura *et al*., 2021).

Government interventions through the Department of Animal Husbandry and Dairying add another dimension to pricing dynamics. The Dairy Entrepreneurship Development Scheme (DEDS) provides tiered subsidies - 25% for milk chilling infrastructure generally and 33% for scheduled caste beneficiaries - directly impacting producers' cost structures and margins (Pandey & Ponnusamy, 2024). These benefits are disproportionately accessed by Farmer Producer Organizations (FPOs), whose members average ₹2,760 annual benefits per milch animal (Ghalawat *et al*., 2022). Surveys of 250 households reveal 37% value subsidy-linked inputs most, followed by 24% prioritizing bonus schemes and 21% premium milk pricing (Pandey & Ponnusamy, 2024). However, subsidy awareness doesn't always translate to better prices - cooperative-affiliated producers demonstrate higher subsidy documentation rates but lower base prices than private suppliers, who benefit from higher gross prices despite lacking formal subsidy channels (Mohapatra *et al*., 2021).

Quality-based pricing implementation varies dramatically between systems. Cooperatives employ precise electronic testing with predefined fat percentage slabs (3.5%, 4.0%, 4.5%) to determine rates, while 86% of private sector suppliers report receiving flat rates regardless of quality (Loura *et al*., 2021). Documentation standards reflect this divide - 92% of cooperative payment slips detail SNF levels, whereas only 21% of private transactions provide receipts, often missing basic details like date or quantity (Gautam *et al*., 2015). Digital payment adoption shows similar disparity, with 76% of cooperative payments using Aadhaar-linked NEFT/DBT systems that enhance traceability, a model showing success in Gujarat where BMCU-linked cooperatives achieve 2.4% lower rejection rates and 31% faster procurement than manual centers (Gurjar *et al*., 2022). Haryana's BMCU systems demonstrate comparable but slightly weaker effects (Loura *et al*., 2021).

Bonus structures remain exclusive to cooperatives, applying rigorous eligibility criteria including minimum 300 liters/month supply and 4.5% average fat content, with payments subject to quarterly cash flow availability (Ghalawat *et al*., 2022). These mechanisms are entirely absent in private systems. Premium pricing through cooperative retail channels (like Vita brand outlets) offers additional remuneration potential, with quality-tiered premiums reaching ₹1.50/liter, though infrastructure limitations restrict this to under 15% of procurement zones (Singh *et al*., 2021). This comprehensive pricing ecosystem demonstrates how institutional structures create fundamentally different economic environments for dairy producers across Haryana's dual-sector system.

6. Profitability and Financial Viability in Haryana

Milk production profitability in Haryana exhibits significant variation across species, operational scale, and marketing channels. Recent 2021 data from Karnal and Jind reveals stark differences in gross returns per liter: ₹46.75 for buffalo milk, ₹42.00 for crossbred cows, and ₹38.60 for indigenous breeds, against respective production costs of ₹40.35, ₹32.48, and ₹31.88 (Mohapatra *et al*., 2021) (Table 1). This translates to net profit margins of ₹6.40, ₹9.52, and ₹6.72 per liter respectively. Commercial operations show even more pronounced differences, with buffalo-based enterprises achieving 21.48% Return on Investment (ROI) versus 35.67% for crossbred herds, requiring break-even yields of 8.1 and 10.4 liters/day respectively (Sahu *et al*., 2012).

Table 1: Product-Level Profit Margins and Processing Costs in Cooperative and Private Dairy Units (Haryana)

Product	Cooperative Margin (%)	Private Margin (%)	Unit Cost (₹/kg or litre)	Primary Sources
Dahi	23.76%	53.00%	₹16.05/kg (coop)	(Singh *et al*., 2021); (Thakur & Dixit, 2020)
Ghee	11.88%	12.75%	NA	(Singh *et al*., 2021); (Thakur & Dixit, 2020)
Paneer	7.76%	NA	₹16.05/kg (coop)	(Singh *et al*., 2021)
Double-toned Milk	15.21%	NA	NA	(Singh *et al*., 2021)
Procurement Cost	₹1.67–₹1.83/L (coop)	Lower, unregulated	-	(Doni & Chauhan, 2019; Singh *et al*., 2021)

Processing profitability follows similarly divergent patterns across product categories. A 2021 zonal audit of cooperative plants showed net margins ranging from 23.76% for dahi down to 7.76% for paneer, after accounting for procurement costs (₹1.83/liter in western Haryana; ₹1.67 eastern), processing, packaging and transport (Singh *et al*., 2021). Informal processors in Karnal outperform these figures dramatically, achieving 53.00% margins on dahi and 31.2% on cream while maintaining 38.2% lower fixed costs than comparable cooperative plants (Thakur & Dixit, 2020).

Comparative financial analysis of cooperative federations reveals persistent performance gaps. During 2001-2011, Punjab's MILKFED consistently outperformed Haryana's DAIRYFED with 6.21% ROE versus 4.14%, and stronger liquidity (current ratio 1.82 vs 1.03), though Haryana showed temporary advantages in asset turnover during 2005-2007 (SINGH). At the processor level, HDDCF units in Rewari and Sonipat achieved 8.3-12.7% ROI, requiring minimum daily outputs of 9,000 liters for standard milk and 6,800 liters for dahi to break even (Chauhan *et al*., 2006).

Producer-level income varies substantially by marketing channel. Cooperative-affiliated producers in Hisar and Mahendragarh average ₹7,850 monthly milk income, while independent private suppliers earn ₹9,360 - reflecting a persistent ₹1.25-₹2.10 per liter price gap (Deepti & Beena Yadav, 2007). Gender disparities compound these differences, with male producers (13.1 liters/day) earning ₹125.64 daily profit versus women's (10.0 liters) ₹92.56 at standard 4.5% fat procurement (Yadav & Grover, 2011).

Supply chain length significantly impacts margins. Direct-to-retail sales in Sonipat and Rohtak yield 19.2% higher per-liter profits than cooperative channels and 11.7% more than standard private procurement (Anonymous, 2020). Cooperative producers receive supplemental bonuses (₹0.50-₹1.25/liter) in 31% of societies, contingent on supplying >300 liters/month and union profitability (Ghalawat *et al*., 2022) - benefits entirely absent in private models.

Hybrid models show intermediate financial outcomes. Public-Private Partnership (PPP) participants in Kaithal, Hisar and Mahendragarh achieve a 0.60 profit-maximization index score, blending input-output margins with livestock asset gains (Raj *et al*., 2020). Smaller cooperatives (<1.2 million liters annual intake) face particular challenges, with 14% in Jhajjar and Bhiwani becoming dormant after three consecutive years of negative margins (Sumit Mahajan *et al*., 2019).

The dairy value chain's financial viability ultimately hinges on four key factors: unit cost control, product diversification, channel selection, and organizational model - with crossbred herds and informal processing currently demonstrating superior returns under prevailing market conditions.

7. Marketing and Supply Chain Management in Haryana

The dairy supply chain in Haryana demonstrates significant cost concentration in milk procurement and logistics operations, with clear regional and structural variations. Cooperative plants under HDDCF exhibit zonal cost differences, reporting mean procurement costs of ₹1.83 per liter in western areas compared to ₹1.67 in eastern zones, according to 2021 audits of high-capacity plants processing over 100,000 liters daily (Singh *et al*., 2021). These costs break down into four primary components: transport (54.57%), chilling (24.00%), collection (17.14%), and reception (8.57%). A granular analysis from Sirsa district reveals slightly different proportions, with transport at 43.72%, chilling at 21.86%, and collection at 26.00%, where costs scale directly with procurement radius and dispatch frequency (Doni & Chauhan, 2019).

Informal sector operations in Karnal present three distinct procurement models with varying efficiency. The intermediary-integrated Model II emerges as most cost-effective at ₹36.10 per liter procurement cost and ₹9.56 net margin per liter, while vendor-dependent Model I suffers from higher fixed costs due to external aggregation needs and spoilage losses (Thakur & Dixit, 2020). Only 42% of these units possess refrigeration infrastructure, with missing chilling capacity directly increasing product loss during extreme weather. This relationship is quantifiable, showing a strong 0.74 correlation ($p<0.01$) between chilling tank capacity and supply chain performance.

Microbiological impacts of cold chain deficiencies are measurable across Haryana's milk flows. Summer sampling along four Rohtak-Panipat routes documents quality degradation: standard plate counts surge from 1.1×10^5 to 4.3×10^5 CFU/mL during 2-hour transport, titratable acidity rises from 0.12% to 0.19%, and coliform levels double by chilling stage (Dahiya & Srivastava, 2012). The absence of mobile chilling units compounds these issues, causing 2.3% spoilage in western routes as measured by lactometer-rejected volumes.

Processing margins vary dramatically by product type. Cooperatives report per-unit returns of ₹6.42/liter (23.76% margin) for dahi, ₹4.11 (15.21%) for double-toned milk, ₹11.36/kg (11.88%) for ghee, and ₹14.77/kg (7.76%) for paneer (Singh *et al*., 2021). Seasonal products like peda and pinni contribute minimally at <3% of annual revenue. Informal private units achieve higher margins (53% on dahi, 12.75% on ghee) through compliance cost savings and local sourcing, with profitability strongly correlated to batch size and shelf life ($R^2=0.61$) (Thakur & Dixit, 2020).

HDDCF's operations involve massive daily throughput - processing 675,000 liters across six unions and supplying 3,800 village societies. Their distribution includes 390,000 liters of poly-packed milk and ~7 tonnes of value-added products daily, utilizing polyethylene-laminated packaging for 98% of standard milk SKUs (Yadav & Grover, 2009). Despite this scale, chilling infrastructure remains limited, with BMCUs present in only 31% of DCSs and active in 15 districts as of 2021.

Marketing channel efficiency shows cooperative advantages. Producers retain 76.16% of consumer price in cooperatives versus 75.15% in private chains (Gurugram-Faridabad data), with cooperatives achieving a 3.20 marketing efficiency index compared to 2.85 for private operators (Mohapatra *et al*., 2022). Local dairies in Sonipat-Rohtak (5-12km radius) outperform both with 19.2% higher margins by eliminating chilling/packaging layers (Thakur *et al*., 2020).

Export activity remains minimal, with just two private units (Ambala/Karnal) holding FSSAI export permits for ghee/UHT milk (<1% volume). HDDCF records no exports, though 6.7% of winter production reaches Delhi NCR, constrained by fragmented cold chains (Sumit Mahajan *et al*., 2019). National Dairy Development Board (NDDB)-led initiatives in Kaithal/Bhiwani are piloting Gujarat's BMCU model which reduced spoilage 27% and shortened delivery cycles 2.1-fold (Gurjar *et al*., 2022).

8. Access to Institutional Support and Finance in Haryana

Formal credit and insurance access remains limited among Haryana's dairy producers, regardless of procurement model. A zonal study of 120 farmers across Karnal, Kaithal, Sirsa, and Hisar revealed only 26.0% accessed institutional livestock loans, with 61.3% relying on self-financing due to procedural hurdles (Ghalawat *et al*., 2022) (Table 2). Regional disparities emerge starkly - Zone I (Karnal-Kaithal) shows mean investments of ₹65,000 per adult female animal with ₹178.40 daily costs, while 78.6% in Zone II (Hisar-Sirsa) cite credit access as a key feed procurement constraint. Alarmingly, 82.5% of surveyed farmers lack livestock insurance coverage, with merely 9.8% having filed claims (Sahu *et al*., 2012). Cooperative linkage improves insurance penetration 2.4-fold through National Livestock Mission integrations and bundled premiums (Kumar *et al*., 2014).

Table 2: Gender-Disaggregated Productivity and Access Indicators in Haryana Cooperative Dairying

Metric	Male Members	Female Members	Source
Avg. Animals Owned	3–5	2	(Yadav & Grover, 2013)
Daily Milk Sale (Litres)	13.1	10.0	(Yadav & Grover, 2013)
Veterinary Access Rate (%)	Higher (not quantified)	Lower	(Deepti & Beena Yadav, 2007)
Training Participation Rate	Higher	Lower	(Deepti & Beena Yadav, 2007)
Awareness of Extension Benefits	>60%	<50%	(Yadav & Dahiya, 2009)

Reproductive health constraints affect 74.3% of herds in Karnal due to absent night-time veterinary coverage and poor semen quality, with anoestrus and repeat breeding most prevalent (Meena & Malik, 2009). Hisar-Sirsa data shows 79.16% deterred by treatment costs, while 51.66% lack block-level diagnostic capacity (Kumar *et al*., 2014). Private channels offer only paravet visits (28.6% coverage) without prophylactic systems (Kumar *et al*., 2021), whereas cooperative areas achieve 63.5% health camp attendance versus 27.2% privately (Singh *et al*., 2010).

A 2024 AHP analysis prioritizes financial subsidies (weight=0.37), training (0.35), demonstrations (0.34), and exposure visits (0.31) as key interventions (Pandey & Ponnusamy, 2024). Cooperative farmers show 2.8× higher training participation, with extension contact scores of 3.42 (±1.1 SD) versus 1.18 privately, and 70.75% vs 51.20% adoption rates (Singh *et al*., 2010). Gender disparities persist - only 27% of women farmers report veterinary/training access versus 96% of male landholders (Bhuyan & Ponnusamy, 2017).

PPP interventions in Kaithal, Hisar, and Mahendragarh achieve 0.62 technical access and 0.60 profit maximization indices (Raj *et al*., 2020). Karnal's innovation platforms show 85% trust in veterinary officers/KVK staff, with >90% receiving breeding info via district teams (Jadhav *et al*., 2023). Cooperative AI centers maintain 78.2% chilled semen supply versus 63% unregulated private sourcing, yielding superior conception rates (Mohapatra *et al*., 2021).

Cooperative-affiliated farmers score significantly higher on knowledge metrics: 2.23 vs 1.41 (animal health) and 2.12 vs 1.38 (milking hygiene) on 3-point Likert scales (Loura *et al*., 2021). Structural analysis reveals only 16.5% have <3km access to equipped clinics, of which 91.2% are cooperative-linked (Kumar *et al*., 2021).

10. Comparative Case Studies in Haryana

The HDDCF operates under a three-tier structure consisting of 6,249 DCSs, 6 milk unions at the district level, and a single apex federation. As of 2022, HDDCF handled 6.75 lakh litres of milk per day, with 4,650 DCSs reporting

daily transactions. Milk was primarily sold in poly-packs and converted to value-added products such as dahi, paneer, ghee, lassi, pinni, and peda, which were distributed via Vita-branded channels in urban Haryana and Delhi NCR (Table 3) (Yadav & Grover, 2009). Members were paid on a fat-content basis at the point of delivery, with payments processed daily. Average daily production and sale per member were 17 and 12 litres, respectively, while in federated zones such as Hisar and Mahendergarh, women producers averaged 10 litres/day compared to 13.1 litres/day among men (Yadav & Grover, 2013).

Table 3: Technical Efficiency and Financial Health of Dairy Institutions in Haryana and Punjab

Indicator	DAIRYFED (Haryana)	MILKFED (Punjab)	Notes	Source
Return on Investment (ROI)	3.8%	6.2%	10-year average (2001–2011)	(SINGH)
Inventory Turnover	2.2	3.6	Plant-level performance metric	(SINGH)
Functional DCSs (2022)	~4,650	Higher (noted)	HDDCF: 25% reported nonfunctional	(Sumit Mahajan *et al*., 2019)
Technical Efficiency (Sirsa)	86.1% (medium farms)	NA	Based on cooperative tenure	(Lal *et al*., 2020)
Peak Daily Procurement (L/day)	6.75 lakh	15.6 lakh	State-level federated network	(SINGH; Yadav & Grover, 2009)

A 10-year financial analysis comparing DAIRYFED (HDDCF) and Punjab's MILKFED showed that MILKFED outperformed DAIRYFED across most key financial indicators. DAIRYFED reported lower return on investment (ROI = 3.8%) and working capital turnover (1.04), while MILKFED reported ROI of 6.2% and higher efficiency across gross profit margin, current ratio, and return on equity (SINGH). Operational performance indicators also favored MILKFED, which reported higher peak procurement (15.6 lakh litres vs. 6.9 lakh litres), larger chilling capacity, and higher growth in functional DCSs (Kaur & Singla, 2024). In contrast, HDDCF showed declining numbers of functional societies and a shrinking average procurement per DCS post-2016, with solvency ratios below sectoral benchmarks (Sumit Mahajan *et al*., 2019).

In terms of profitability, product-level financials from 2021 revealed that HDDCF's cooperative milk plants earned a 23.76% margin on dahi, 15.21% on double-toned milk, and 11.88% on ghee, with paneer returning the lowest at 7.76% (Singh *et al*., 2021). Processing costs were higher in the western zone (₹1.83/litre) than the eastern zone (₹1.67/litre), largely due to transport and chilling expenditures. Members received daily payouts with periodic access to veterinary camps and AI services coordinated through union-level health officers. In cooperative-linked villages, technical efficiency scores of dairy farmers exceeded 80%, with highest scores observed in medium-herd categories due to scale consistency and longer cooperative membership duration (Lal *et al*., 2020).

Private-sector dairy models in Haryana operate predominantly in informal and semi-formal structures, especially in districts like Karnal, Panipat, and Ambala. An economic evaluation of 27 private processing units in Karnal reported product-specific profit margins of 53% for dahi and 12.75% for ghee, with margins increasing alongside processing capacity (Thakur & Dixit, 2020). Units with daily intake above 800 litres exhibited a 38% reduction in fixed cost per litre. While these units showed strong short-term solvency, they lacked standardized procurement models and had limited access to quality control infrastructure. Organizationally, private processors relied on vendor networks or direct procurement, with only 15% maintaining formal chilling facilities and just 9% operating licensed veterinary or feed linkages.

A PPP pilot implemented in Kaithal, Hisar, and Mahendragarh found that private extension agents, known as Gopal workers, achieved an effectiveness index of 0.60 in profit maximization and 0.62 in technical service access, but scored only 0.48 on transparency due to lack of grievance mechanisms (Raj *et al*., 2020). In contrast, HDDCF's federated extension channels included trained veterinary staff, cold-chain-linked AI centers, and periodic training programs, contributing to significantly higher adoption of scientific dairy practices (Singh *et al*., 2010).

Additional comparative evidence from quality-of-life studies showed that cooperative membership was associated with monthly income gains between ₹300 and ₹3,500, a reduction in dependence on private vendors, and increased expenditure on child health and education (Deepti & Beena Yadav, 2007). In performance benchmarking, cooperative-affiliated producers demonstrated higher daily milk output per animal and superior reproductive indicators, such as shorter inter-calving intervals and reduced calf morbidity in National Dairy Research Institute (NDRI)-adopted cooperative villages (Meena *et al*., 2017).

In organizational structure, HDDCF maintains standardized procurement, pricing transparency, and centralized veterinary care, while private-sector entities prioritize flexibility and speed but operate without formal input subsidies or structured training support. Comparative field assessments consistently show that cooperatives outperform private dairies on long-term economic stability, herd health outcomes, and extension penetration, though private units demonstrate superior product-level margins and lower operating latency.

9. Future Research and Policy Directions

Haryana's dairy sector faces significant operational and economic challenges that hinder its sustained growth and efficiency. One critical issue is inadequate infrastructure and cold chain management, particularly within cooperative systems. Limited chilling facilities and fragmented cold chains directly compromise milk quality, elevating microbiological risks and leading to increased spoilage rates. Transportation accounts for a major proportion of cooperative procurement costs, further exacerbating financial strains. Informal private units, while operationally leaner, similarly struggle due to insufficient refrigeration infrastructure, which intensifies during peak summer months when spoilage dramatically rises, negatively impacting profitability.

Another prominent concern is milk price volatility and associated market risks, profoundly affecting farmers' income stability. Cooperatives employ structured pricing based on precise milk quality metrics like fat and solids-not-fat content. However, they generally offer lower procurement prices than private dairies, especially during peak demand periods such as festivals, causing farmer migration towards informal markets. Private dairies often provide higher, albeit unregulated prices, lacking transparency and standardized quality benchmarks. This discrepancy creates uncertainty for producers regarding income predictability, further complicating economic planning at the farm level.

Quality control, adulteration, and compliance emerge as persistent regulatory challenges in both cooperative and private dairy segments. Cooperative units, despite maintaining standardized testing protocols, frequently encounter operational inefficiencies that hamper consistent compliance. Private units, largely unregulated, pose substantial food safety risks through inconsistent quality assurance processes and limited oversight. This regulatory gap underscores the need for strengthened food safety frameworks and standardized enforcement mechanisms to enhance consumer trust and safeguard public health.

Addressing farmer grievances and dispute resolution is another vital but neglected area. Cooperative governance structures offer formalized platforms for grievance management, yet these systems often lack efficacy, transparency, and timely resolution, contributing to member dissatisfaction. In contrast, private dairies generally lack structured grievance mechanisms, leaving producers vulnerable to exploitation without clear avenues for addressing disputes, especially regarding payment delays and quality assessments.

Synthesizing these challenges reveals a clear dichotomy between cooperative and private dairy systems: cooperatives prioritize transparency and inclusivity but suffer from operational inefficiencies and market rigidities, whereas private entities excel in profitability and market agility but often compromise producer welfare and regulatory compliance. The sector's complexity demands integrated policy approaches that reconcile market efficiency with equitable producer support.

Several areas necessitate further research to inform targeted interventions. Critical among these are comprehensive comparative cost-benefit analyses across cooperative and private processing units, systematic evaluation of cold chain logistics improvements, and deeper investigations into the economic impacts of digital technologies for procurement and payment systems. Additionally, gender-disaggregated data must be expanded to adequately address disparities in access to veterinary services, training, and market information. Finally, exploring models for effective public-private partnerships could bridge existing gaps, enhancing productivity, profitability, and sustainability within Haryana's dairy landscape.

Declaration and statement

Author Contributions

All authors contributed significantly to the conceptualization, design, data collection, analysis, and writing of the manuscript. The corresponding author supervised the overall research work and critically revised the manuscript. All authors have reviewed and approved the final manuscript.

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