

# Analysis on Optimization Countermeasures of Dairy Enterprise Supply Chain Under the Background of Digital Intelligence

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**Abstract:** In recent years, the dairy industry has faced challenges of rising costs and diversified demands, and digital intelligence transformation is the key to supply chain upgrading. Taking M dairy enterprise as an example, this study explores the role of digital transformation and proposes an optimization scheme centered on “bioactivity management.” It focuses on analyzing key technologies such as the Internet of Things (IoT), artificial intelligence (AI), blockchain, and automation: integrating IoT to realize full-chain activity monitoring, applying AI to improve prediction accuracy and flexible production scheduling, using blockchain to build a transparent traceability system, and incorporating bioactivity indicators into the core evaluation system. The research shows that the scheme not only provides a practical guide for M enterprise, but also its strategies have important reference significance for improving the supply chain efficiency of the industry, ensuring quality, and realizing sustainable development.

**Keywords:** Digital intelligence; Dairy supply chain; Internet of Things (IoT); Blockchain; Bioactivity management

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## 1. Introduction

With the accelerated digital transformation of the global economy, digital intelligence technologies are profoundly reshaping industrial operation models. As a key component of the food industry, the dairy industry is facing an increasingly complex market environment, fierce competitive pressure, and higher consumer requirements for food safety, quality traceability, and product diversification. The formation of dairy quality involves the collaboration of multiple links, such as breeding, processing, and sales. Therefore, building a full-process supply

chain management and quality collaborative control system has become the key to improving dairy quality and safety as well as industry competitiveness <sup>[1-2]</sup>.

Supply Chain Management (SCM) takes the cross-organizational collaborative network as the carrier, and realizes systematic management from raw material procurement to terminal consumption by integrating logistics, information flow, and capital flow <sup>[3]</sup>. Digital Intelligence is driven by data as the core, combining technologies such as artificial intelligence, cloud computing, and the Internet of Things to promote the intelligent upgrading of business processes and decision optimization <sup>[4]</sup>. Driven by new intelligent technologies, the traditional supply chain management model has been difficult to adapt to the rapidly changing market environment. Dairy enterprises urgently need to optimize the supply chain through digital intelligence technologies to improve operational efficiency and market response capabilities. As a dynamic perception and intelligent interconnection network system, the Internet of Things has greatly improved the transparency and collaborative efficiency of the Dairy Supply Chain (DSC) through embedded systems and real-time data collection. It applies technologies such as Radio Frequency Identification (RFID), big data, and intelligent manufacturing to optimize production processes by providing real-time data and controlling operational processes in the supply chain <sup>[5]</sup>.

## **2. Research status and challenges**

Digital transformation has a profound impact on supply chain management. It covers the entire process from R&D, production, to marketing and logistics, emphasizing the seamless connection of various links to improve overall efficiency. Domestic scholars' research shows that digital transformation can reduce resource waste through information visualization and business collaboration, thereby enhancing supply chain efficiency <sup>[5-6]</sup>. Enterprises' fulfillment of digital responsibilities has a positive effect on commercial credit financing, and the implementation of digital strategies can effectively improve enterprise efficiency, reduce costs, and optimize production quality and efficiency. In addition, facing challenges in technology application and data security, enterprises need to strengthen infrastructure construction. Studies also point out that digital transformation has brought significant efficiency improvements, especially to non-state-owned enterprises and regions with a high degree of marketization. In the future, digital transformation will promote the improvement of supply chain transparency and performance, and further optimize collaboration through technologies such as big data and cloud computing <sup>[7]</sup>. These trends point to a more efficient and flexible supply chain ecosystem. In the digital intelligence transformation of dairy enterprises and related enterprises, foreign research on digital management models covers multiple key areas. Although the application of digital technologies has significantly improved the sustainability of the supply chain, technical complexity and talent shortage remain obstacles to implementation <sup>[8]</sup>.

## **3. In-depth analysis and cause exploration of supply chain management**

### **3.1. Analysis of pain points and difficulties in each link**

Although the supply chain management of M dairy enterprise has reached the industry-leading level, its full-link operation still faces multi-dimensional systematic challenges. These pain points stem not only from the special attributes of the dairy industry, such as sensitivity to bioactivity and strict time constraints, but also from complex factors such as long industrial chains, many participating entities, and large environmental fluctuations. Furthermore, deep-seated contradictions between technical adaptability and organizational collaboration have been exposed in the process of digital transformation.

Milk source supply is the starting point of the dairy supply chain and one of the most unstable links <sup>[9]</sup>. For example, in North China, milk trucks need to detour multiple milk collection points every day, resulting in an average time of 34 hours from milking to canning. This time loss directly leads to the risk of microbial proliferation, and the average total number of colonies in raw milk increases. This forces the subsequent sterilization temperature to rise by 0.3°C, resulting in an increase in the loss rate of active substances such as lactoferrin to 15%. Therefore, the core difficulty of the dairy supply chain lies in the contradictory relationship between bioactivity preservation and logistics costs. Monitoring data shows that the temperature fluctuation in the loading and unloading links of low-temperature products reaches  $\pm 3.5^{\circ}\text{C}$ , leading to a decrease in the survival rate of active lactic acid bacteria from 98% at the factory to 72% at the terminal. Third-party logistics enterprises specializing in dairy transportation account for less than 20% of the industry. Most enterprises need to carry goods such as meat and seafood at the same time, resulting in mixed temperature zone settings of vehicles (such as the mixed use of  $-18^{\circ}\text{C}$  freezers and  $2^{\circ}\text{C}$  refrigerated trucks), making it difficult to guarantee temperature control accuracy. **Table 1** shows the impact of temperature fluctuations in different cold chain links on dairy quality and the rate of increase in cargo damage costs.

**Table 1.** The impact of temperature fluctuations in cold chain links on dairy quality

| Links with temperature control failure | Temperature fluctuation range | Loss rate of active substances | Increase the rate of cargo damage costs |
|----------------------------------------|-------------------------------|--------------------------------|-----------------------------------------|
| Trunk line transportation              | $\pm 1.2^{\circ}\text{C}$     | 8%                             | 15%                                     |
| Urban transfer                         | $\pm 3.5^{\circ}\text{C}$     | 26%                            | 40%                                     |
| Terminal storage                       | $\pm 5.8^{\circ}\text{C}$     | 45%                            | 120%                                    |

Generally, dairy enterprises have thousands of raw material suppliers, but the lack of a classified management mechanism leads to resource misallocation. For example, among packaging suppliers, strategic suppliers account for only 15%, yet their supplied sterile packaging directly affects product shelf life; in contrast, ordinary suppliers (such as carton manufacturers), which account for 60% of the total, consume 80% of the audit resources. This management imbalance has exacerbated the risk transmission effect. For instance, in 2022, an oil supplier suspended production due to environmental penalties, and the switching cycle for alternative suppliers reached 45 days, resulting in a production shutdown loss of over 100 million yuan for the high-end yogurt product line. In global procurement, geopolitical risks have been further amplified—Australian whey powder prices rose by approximately 40% due to changes in tariff policies, but the contract price-locking mechanism prevented dynamic adjustments to procurement costs, compressing the gross profit margin by 12 percentage points. **Table 2** shows the comparison of technical input and output among pastures of different scales.

**Table 2.** Comparison of technical input and output among pastures of different scales

| Pasture type                    | Mechanized milking rate | Daily milk production per cow (kg) | Colony control compliance rate | Annual investment return rate |
|---------------------------------|-------------------------|------------------------------------|--------------------------------|-------------------------------|
| Self-operated pasture           | 100%                    | 32.5                               | 99%                            | 18%                           |
| Cooperative large-scale pasture | 95%                     | 28.7                               | 92%                            | 9%                            |
| Small and medium-sized pasture  | 68%                     | 21.4                               | 76%                            | -3%                           |

To sum up, the supply chain pain points of M dairy enterprise reveal three major structural conflicts in the dairy industry. Firstly, there is the conflict between bioactivity management and industrial efficiency goals. The requirement for preserving active substances in low-temperature dairy products (such as the total number of colonies  $\leq 100,000$  CFU/mL) is inherently contradictory to the cost control of large-scale transportation, forcing enterprises to make a difficult trade-off between quality compromise and market contraction. Secondly, there is an imbalance between technological leapfrogging and organizational inertia. Although digital technologies have achieved data connection from pastures to factories, behaviors such as stockpiling, price undercutting, and information shielding in the distributor system have hindered the flow of real data across the entire chain. Finally, there is the tension between economies of scale and regional differences. The national network layout is difficult to adapt to the characteristics of regional markets, leading to sustained tension in the triangular relationship of “production-sales-inventory.”

### 3.2. Collection and analysis of relevant data

The supply chain data system of M dairy enterprise is built on a three-layer architecture of “Global Perception—Intelligent Hub—Decision Empowerment.” Through the in-depth integration of IoT, blockchain, and AI, it has achieved a full-chain data connection from raw milk in pastures to terminal consumption. Data collection covers the following four core dimensions.

(1) Bioactivity data at the milk source end: Real-time collection of cow health indicators (such as rumination frequency, body temperature fluctuation), milk production, and raw milk components (fat content, total number of colonies, somatic cell count) through cow collar sensors and milking equipment monitoring terminals. Each cow generates more than 500 data points per day on average. Combined with blockchain certification to ensure data immutability, a full-life-cycle database of “digital cows” is formed. (2) Dynamic efficiency data in the production link: The Manufacturing Execution System (MES) tracks the production line status in real time and records parameters such as Overall Equipment Efficiency (OEE), product changeover time, energy consumption, and water consumption. Taking the Ningxia factory as an example, the sensors of the UHT production line collect temperature and pressure data every 5 seconds, and optimize the sterilization parameters through edge computing, increasing the retention rate of lactoferrin activity by 7 percentage points. (3) Spatiotemporal trajectory data of cold chain logistics: Cold chain vehicle-mounted GPS and temperature-humidity sensors generate data streams such as logistics routes, temperature control compliance rates, and loading/unloading durations. (4) Multi-source feedback data of the consumer market: Integrate distributor Enterprise Resource Planning (ERP) orders, terminal POS scanning records, e-commerce platform reviews, and social media public opinion to build a demand forecasting matrix. The core data collection indicator system for the supply chain of M dairy enterprise is shown in **Table 3**.

**Table 3.** Core data collection indicator system for the supply chain of enterprise M

| Data category          | Collection indicators                                                                  | Technical means                                       | Update frequency |
|------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------|------------------|
| Milk Source Quality    | Total Number of Colonies, Somatic Cell Count, Milk Production                          | IoT Sensors + Blockchain                              | Real-time        |
| Production Efficiency  | Overall Equipment Efficiency (OEE), Changeover Time, Unit Energy Consumption           | Manufacturing Execution System (MES) + Edge Computing | Every 5 seconds  |
| Cold Chain Reliability | Temperature Control Compliance Rate, Loading/Unloading Duration, Path Deviation Degree | GPS + Temperature-Humidity Sensors                    | Every 1 minute   |
| Demand Fluctuation     | Order Distortion Rate, Inventory Turnover Days                                         | API Connection + AI Prediction Model                  | Every 15 minutes |

## 4. Optimization strategies and implementation plans

### 4.1. Strategic framework for digital intelligence transformation

The core of M dairy enterprise's digital intelligence transformation strategy lies in building a smart supply chain ecosystem driven by both "activity management" and "global collaboration." It reconstructs the value creation logic of the dairy industry through data connection—upgrading the traditional linear supply chain centered on cost control into an agile network with bioactivity retention rate as the core indicator. In terms of specific goal setting, M dairy enterprise focuses on three dimensions: bioactivity management, full-chain collaboration, and sustainable development. Relying on IoT and blockchain technologies, it realizes full-chain activity traceability of raw milk from milking to the consumer terminal, controls the total number of colonies, and increases the retention rate of core active substances such as lactoferrin by about 20 percentage points. The scientificity of this goal lies in the exponential characteristic of the dairy activity attenuation curve. Secondly, it builds a demand-driven dynamic response network, reducing the proportion of emergency production scheduling for fragmented orders such as community group buying by about 30%. This goal directly addresses the inherent contradiction of high loss in the dairy industry—the conflict between bioactivity timeliness and industrial efficiency, which needs to be resolved through the precise synchronization of the data clock and biological clock. Finally, at the level of sustainable development, it establishes a balance model between carbon emissions and economic benefits, covers 80% of cooperative pastures through "pasture carbon accounts", reduces the carbon emission intensity per ton of raw milk, and reshapes the economic feasibility of the green supply chain <sup>[10–13]</sup>. **Table 4** shows the digital intelligence transformation goal system of M dairy enterprise in the three dimensions.

**Table 4.** Digital intelligence transformation goal system of M dairy enterprise

| Dimension                | Core indicator                                | Baseline level | Target value | Technical support                                               |
|--------------------------|-----------------------------------------------|----------------|--------------|-----------------------------------------------------------------|
| Bioactivity Management   | Lactoferrin Retention Rate                    | 78%            | 95%          | Blockchain Traceability + Dynamic Temperature Control Algorithm |
| Full-Chain Collaboration | Proportion of Emergency Production Scheduling | 40%            | 10%          | LSTM Demand Forecasting Model + Flexible Production Line        |
| Sustainable Development  | Carbon Emission Intensity per Ton of Raw Milk | 1.2 tons       | 0.8 tons     | IoT for Manure Power Generation + Feed Optimization Model       |

### 4.2. Supply chain optimization suggestions and continuous improvement

To achieve the above strategic goals, the corresponding relationship between resource allocation and organizational adjustment of M dairy enterprise is shown in **Table 5**.

**Table 5.** Corresponding relationship between resource allocation and organizational adjustment

| Strategic requirements         | Resource allocation plans                                                      | Organizational structure innovations               | Efficiency improvement indicators                 |
|--------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------|---------------------------------------------------|
| Precise Control of Bioactivity | Invest 500 million yuan to deploy optical sensors for milking robots           | Establish Bioactivity Research Institute           | Colony detection efficiency increased by 50 times |
| Response to Fragmented Orders  | Build regional small and micro factories (single factory capacity: 5 tons/day) | Set up the Agile Factory Project Department        | Cost of small-batch orders reduced by 35%         |
| Full-Chain Data Connection     | Construct blockchain data sovereignty pool                                     | Establish Supply Chain Federated Learning Alliance | Inventory visibility error rate reduced to 2%     |

The supply chain performance evaluation of M dairy enterprise should be centered on the “bioactivity retention rate.” The bioactivity management dimension focuses on the core value of dairy products, and real-time tracks indicators such as the total number of raw milk colonies (target  $\leq 30,000$  CFU/mL), lactoferrin retention rate (target  $\geq 95\%$ ), and cold chain temperature control compliance rate ( $\pm 0.5$  °C fluctuation threshold) through IoT sensors. Aiming at the short shelf-life characteristics of dairy products, the timeliness and response dimension designs dynamic response indicators. It improves prediction accuracy by integrating dynamic factors such as social media public opinion and weather warnings, and increases the processing efficiency of small-batch orders by 40% relying on modular cellular production lines. For the cold chain breakpoint repair speed (AI dispatch response  $\leq 15$  minutes after temperature control exceeds the standard), the cargo damage rate is reduced through a three-level intelligent work order system. These indicators directly address the core contradiction of high loss in the dairy industry—the conflict between the timeliness of bioactivity and fragmented market demand, which needs to be accurately responded to through data-driven approaches <sup>[14–15]</sup>.

## 5. Results and prospects

This paper conducts a systematic analysis of the supply chain management optimization of M dairy enterprise in the background of digital intelligence transformation. The research profoundly explores the uniqueness of the dairy supply chain that distinguishes it from other industries. Its core value lies in the effective control of the bioactivity of products (such as the activity retention of lactoferrin and probiotics), while it is restricted by inherent attributes such as strict time constraints, long structural chains, and diverse participating entities. It also accurately identifies key challenges commonly faced by the industry currently, such as cost pressure, quality risks, collaborative obstacles, and transformation barriers. The core innovation of M dairy enterprise is to establish “bioactivity management” as the value anchor and integrate it into the entire optimization process. It also innovatively incorporates key bioactivity indicators such as the “72-hour lactoferrin retention rate” into the core performance evaluation system. Through data mining and simulation analysis, the expected effectiveness of this framework in improving the efficiency, resilience, and sustainability of the enterprise’s supply chain has been verified.

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