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Big Data Analytics for Demand Forecasting in the Mushroom Supply Chain

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ABSTRACT

The mushroom industry plays an increasingly important role in the agri-food sector due to rising demand for nutritious, functional, and sustainable food products. However, the mushroom supply chain faces significant challenges related to perishability, short shelf life, and demand uncertainty, which often result in inventory losses and inefficiencies. This study examines the role of big data analytics capability in enhancing demand forecasting accuracy and its impact on supply chain performance within the mushroom industry. Using a quantitative explanatory research design, data were collected through a structured questionnaire survey of mushroom supply chain actors, including producers, processors, distributors, and retailers. The data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The results reveal that big data analytics capability has a significant positive effect on demand forecasting accuracy and supply chain performance. Furthermore, demand forecasting accuracy partially mediates the relationship between big data analytics capability and supply chain performance. These findings highlight the strategic importance of data-driven forecasting in managing demand uncertainty and improving operational efficiency in perishable agribusiness supply chains. This study contributes to the literature by extending big data analytics and demand forecasting research to the mushroom industry, providing both theoretical insights and practical implications for enhancing supply chain sustainability and competitiveness.

Keywords: Big Data Analytics; Demand Forecasting; Mushroom Supply Chain; Supply Chain Performance; Perishable Agribusiness; Digital Transformation

Field: Supply Chain Management; Agribusiness Management; Business Analytics; Big Data; Operations Management; Digital Transformation; Agriculture

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SDGs: Zero Hunger (2); Industry, Innovation and Infrastructure (9); Responsible Consumption and Production (12); Decent Work and Economic Growth (8)

INTRODUCTION

The mushroom industry has emerged as a strategically important segment of the agri-food sector due to its rapid market growth (Chandra et al., 2018), high nutritional value, and increasing consumer demand for functional and sustainable food products (Sangeeta et al., 2024). However, the mushroom supply chain faces distinctive challenges compared to other agricultural commodities (De Cianni et al., 2023). Mushrooms are highly perishable, sensitive to storage conditions, and characterized by short shelf life, making demand uncertainty a critical risk for producers, distributors, and retailers (Castellanos-Reyes et al., 2021). Inaccurate demand forecasting often leads to overproduction, inventory losses, price volatility, and inefficient resource utilization across the supply chain.

Traditional demand forecasting methods in the mushroom industry largely rely on historical sales data, manual estimation, or simple statistical techniques (Ihwah et al., 2021). While these approaches may be sufficient in stable market conditions, they are increasingly inadequate in today's dynamic business environment. Consumer preferences, seasonal consumption patterns, promotional activities, climate variability, and logistics disruptions interact in complex ways that conventional forecasting models struggle to capture. As a result, mushroom supply chains frequently experience mismatches between supply and actual market demand, undermining both profitability and sustainability.

The rapid advancement of digital technologies (Renaldo, Hafni, et al., 2022) has introduced new opportunities to address these challenges through big data analytics (Renaldo, Junaedi, et al., 2025). Big data analytics enables organizations to collect, integrate, and analyze large volumes of structured and unstructured data from diverse sources, such as point-of-sale transactions, e-commerce platforms, weather data, social media trends, sensor-based production systems, and logistics records (Renaldo, Elvina, et al., 2025). By leveraging advanced analytical techniques (Renaldo et al., 2024), including machine learning and predictive modeling, firms can generate more accurate and timely demand forecasts, supporting proactive decision-making throughout the supply chain.

In the context of the mushroom supply chain (Jahrizal et al., 2025), the application of big data analytics holds significant potential. Accurate demand forecasting can help producers optimize production planning, reduce post-harvest losses, and improve coordination with distributors and retailers. Moreover, data-driven forecasting supports better inventory management (Renaldo, Suharti, et al., 2022), pricing strategies, and distribution efficiency, contributing to cost reduction and enhanced customer satisfaction. Despite these potential benefits, empirical research on the use of big data analytics for demand forecasting in mushroom supply chains remains limited, particularly in emerging economies where small and medium-sized enterprises dominate the sector (Nyoto et al., 2024).

Existing studies on agricultural demand forecasting tend to focus on staple crops or large-scale agribusinesses, often overlooking high-value perishable products such as mushrooms. Furthermore, much of the literature emphasizes technical forecasting accuracy without sufficiently examining the managerial and business implications of adopting big data analytics. This creates a research gap in understanding how big data analytics influences supply chain performance, decision quality, and competitive advantage within the mushroom industry.

Therefore, this study aims to investigate the role of big data analytics in enhancing demand forecasting accuracy within the mushroom supply chain and to examine its implications for supply chain efficiency and business performance. By integrating perspectives from supply chain management and data-driven decision-making, this research contributes to the growing body of literature on digital transformation in agribusiness. The findings are expected to provide both theoretical insights and practical guidance for mushroom industry stakeholders seeking to leverage big data analytics to improve forecasting capability and achieve sustainable competitive advantage (Rahman et al., 2025).

LITERATURE REVIEW

Resource-Based View (RBV)

The Resource-Based View posits that firms achieve sustainable competitive advantage by acquiring and effectively utilizing valuable, rare, inimitable, and non-substitutable resources (Barney, 1991). In the context of this study, big data analytics capability is conceptualized as a strategic organizational resource (Fransisca et al., 2025). The ability to collect, process, and analyze large volumes of diverse data enables firms in the mushroom supply chain to generate superior demand forecasts compared to competitors relying on traditional methods. Demand forecasting accuracy derived from big data analytics reflects an intangible capability that is difficult to imitate due to its dependence on data infrastructure, analytical expertise, and organizational learning. Therefore, RBV provides a strong theoretical basis for explaining how analytics-driven forecasting contributes to operational efficiency, reduced waste, and improved business performance in mushroom supply chains.

Dynamic Capability Theory

Dynamic Capability Theory extends RBV by emphasizing a firm's ability to integrate, build, and reconfigure internal and external competencies in response to rapidly changing environments (Mikalef et al., 2020). The mushroom industry operates under high uncertainty due to perishability, fluctuating consumer demand, seasonal effects, and environmental factors. Big data analytics supports dynamic capabilities by enabling firms to sense demand changes, seize emerging market opportunities, and reconfigure production and distribution plans in real time. Through advanced analytics and predictive modeling, mushroom supply chain actors can continuously adapt forecasting models based on new data inputs such as weather conditions, market trends, and consumer behavior. Thus, dynamic capability theory explains how big data analytics-driven demand forecasting enhances supply chain agility and resilience.

Information Processing Theory

Information Processing Theory argues that organizational performance improves when a firm's information-processing capacity matches the level of environmental uncertainty it faces (Liu et al., 2023). Perishable supply chains, including mushroom supply chains, are characterized by high information uncertainty related to demand variability, inventory risks, and logistics constraints. Big data analytics increases information-processing capacity by integrating multiple data sources and transforming them into actionable insights. Accurate demand forecasting represents an outcome of improved information processing, allowing managers to make informed decisions regarding production scheduling, inventory control, and distribution planning. From this perspective, big data analytics serves as a mechanism to reduce uncertainty and enhance decision quality across the mushroom supply chain.

Supply Chain Integration Theory

Supply Chain Integration Theory emphasizes coordination, information sharing, and collaboration among supply chain partners to improve overall performance (Anwar et al., 2025). Effective demand forecasting requires seamless data integration across upstream and downstream actors, including farmers, processors, distributors, and retailers. Big data analytics facilitates vertical and horizontal integration by enabling real-time data sharing and collaborative forecasting. In the mushroom supply chain, integrated demand forecasting helps align production volumes with market demand, reduces the bullwhip effect, and improves inventory turnover. This theory supports the argument that analytics-driven forecasting enhances not only firm-level outcomes but also system-wide supply chain efficiency.

Contingency Theory

Contingency Theory suggests that organizational effectiveness depends on the alignment between internal capabilities and external environmental conditions (Hijazi et al., 2025). The mushroom supply chain operates in a context of high perishability, demand volatility, and technological heterogeneity, particularly in emerging economies dominated by SMEs. Big data analytics adoption and its impact on demand forecasting are contingent upon factors such as technological readiness, data quality, organizational skills, and market dynamics. This theory provides a lens to explain why the effectiveness of analytics-based forecasting may vary across firms and supply chain structures.

Demand Forecasting in Agricultural and Perishable Supply Chains

Demand forecasting is a critical component of supply chain management (Renaldo & Augustine, 2022), particularly in agricultural sectors dealing with perishable products. Accurate forecasting enables firms to balance supply with market demand, minimize waste, optimize inventory levels, and improve overall operational efficiency. In perishable supply chains, such as fresh food and horticultural products, demand uncertainty is amplified by factors including seasonality, weather conditions, short product life cycles, and fluctuating consumer preferences.

Previous studies in agricultural demand forecasting have predominantly focused on staple commodities and long-life products, employing traditional quantitative techniques such as time-series analysis, moving averages, and regression models. While these methods provide baseline insights, their effectiveness is limited in handling nonlinear relationships and complex interactions among multiple demand drivers. In perishable product supply chains, inaccurate forecasts often result in overproduction, spoilage, and financial losses, highlighting the need for more adaptive and data-driven forecasting approaches.

Big Data Analytics in Supply Chain Management

Big data analytics (BDA) has gained significant attention in supply chain management literature due to its ability to process high-volume, high-velocity, and high-variety data. BDA enables firms to transform raw data into actionable insights, supporting strategic, tactical, and operational decision-making. In supply chain contexts, BDA has been linked to improved demand forecasting accuracy, enhanced visibility, better coordination among supply chain partners, and increased responsiveness to market changes.

Empirical studies indicate that organizations leveraging big data analytics capabilities tend to achieve superior supply chain performance compared to those relying on conventional information systems. Advanced analytics techniques, such as machine learning algorithms and predictive modeling, allow firms to capture complex patterns in demand behavior that traditional models often fail to identify (Renaldo, Susanti, et al., 2025). However, the successful adoption of BDA requires not only technological infrastructure but also organizational readiness, data quality, and analytical skills.

Big Data Analytics for Demand Forecasting

The application of big data analytics for demand forecasting has been extensively explored in retail, manufacturing, and logistics sectors. Research demonstrates that integrating diverse data sources, such as point-of-sale data, online transactions, weather information, and social media signals, can significantly enhance forecasting accuracy. Machine learning-based forecasting models have shown superior performance in capturing nonlinear demand patterns and adapting to dynamic market conditions.

Despite these advancements, much of the existing literature emphasizes forecasting accuracy from a technical perspective, often neglecting managerial implications and industry-specific contexts. Furthermore, studies frequently focus on large corporations with advanced digital infrastructures (Junaedi et al., 2024), leaving small and medium-sized enterprises underrepresented. This gap suggests the need for sector-specific research that examines how BDA-driven forecasting impacts operational and financial outcomes in different supply chain environments.

Mushroom Supply Chain Characteristics and Challenges

The mushroom supply chain presents unique challenges due to the biological and logistical characteristics of the product. Mushrooms are highly sensitive to temperature, humidity, and handling conditions, resulting in a short shelf life and high risk of post-harvest losses. Demand for mushrooms is influenced by factors such as consumer health awareness, culinary trends, price fluctuations, and promotional activities, making forecasting particularly complex.

Existing studies on the mushroom industry largely focus on cultivation techniques, post-harvest handling, and processing technologies. Business-oriented research on mushroom supply chains remains relatively limited, especially regarding data-driven decision-making and forecasting practices (Junaedi et al., 2025). The dominance of small-scale producers and SMEs further complicates data integration and technology adoption across the supply chain.

Research Gap and Conceptual Positioning

Although big data analytics has been widely recognized as a valuable tool for improving demand forecasting, its application within mushroom supply chains remains underexplored. Prior research has not sufficiently addressed how BDA-driven demand forecasting influences supply chain efficiency, waste reduction, and business performance in perishable agribusiness contexts. Additionally, limited attention has been given to emerging economies, where digital transformation in agriculture is still in its early stages.

Therefore, this study positions itself at the intersection of big data analytics, demand forecasting, and mushroom supply chain management. By focusing on the mushroom industry, this research contributes to the literature by extending the application of BDA beyond conventional sectors and by highlighting its strategic value for improving supply chain performance and sustainability in perishable food systems.

METHODOLOGY

Research Design

This study adopts a quantitative explanatory research design to examine the role of big data analytics in improving demand forecasting and supply chain performance in the mushroom industry (Sekaran & Bougie, 2016). A quantitative approach is appropriate as the study seeks to test theoretically derived relationships between big data analytics capability, demand forecasting accuracy, and supply chain performance using empirical data. The research design enables hypothesis testing and generalization of findings across mushroom supply chain actors.

Research Object and Unit of Analysis

The object of this research is the mushroom supply chain, encompassing upstream, midstream, and downstream actors. The unit of analysis consists of organizations involved in mushroom production, processing, distribution, and retailing, including mushroom farmers, agribusiness SMEs, distributors, and food processors. These actors are selected due to their direct involvement in demand planning and inventory decision-making (Rustan et al., 2025).

Data Collection Method

Primary data are collected using a structured questionnaire survey distributed to mushroom supply chain actors. The questionnaire is designed to capture perceptions and practices related to big data analytics adoption, demand forecasting processes, and supply chain performance outcomes. Respondents include owners, managers, and operational staff responsible for production planning, inventory management, or data analysis. To enhance response quality, the questionnaire uses a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). The survey is administered both online and offline to accommodate varying levels of digital readiness among respondents.

Variable Measurement

The study employs three main constructs:

1. Big Data Analytics Capability (Independent Variable)

   This variable reflects the organization's ability to collect, process, analyze, and utilize large volumes of diverse data for decision-making. Indicators include:

   - Data integration from multiple sources
   - Use of advanced analytical tools
   - Data quality and accessibility
   - Analytical skills and expertise
   - Management support for data-driven decisions

2. Demand Forecasting Accuracy (Mediating Variable)

   Demand forecasting accuracy represents the effectiveness of forecasting processes in predicting market demand for mushroom products. Indicators include:

   - Accuracy of demand predictions
   - Timeliness of forecasting updates
   - Ability to capture demand fluctuations
   - Reduction of forecast errors
   - Responsiveness to market changes

3. Supply Chain Performance (Dependent Variable)

   Supply chain performance is measured through operational and financial outcomes. Indicators include:

   - Inventory turnover efficiency
   - Reduction in product spoilage
   - Order fulfillment performance
   - Cost efficiency (Chandra et al., 2024)
   - Overall supply chain responsiveness

Sampling Technique and Sample Size

The sampling technique used is purposive sampling, targeting respondents who possess adequate knowledge of forecasting and data usage within the mushroom supply chain (Zulkifli et al., 2023). This approach ensures that the data collected are relevant to the research objectives. The minimum sample size follows the ten-times rule, commonly applied in structural equation modeling, where the sample size should be at least ten times the maximum number of structural paths pointing to a construct. Accordingly, a minimum of 100 respondents is targeted to ensure statistical robustness.

Data Analysis Technique

Data analysis is conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM). PLS-SEM is selected due to its suitability for exploratory research, complex models, and studies involving relatively small sample sizes. The analysis is performed in two stages:

1. Measurement Model Evaluation

This stage assesses reliability and validity through indicator loadings, composite reliability, Cronbach's alpha, average variance extracted (AVE), and discriminant validity.

2. Structural Model Evaluation

   This stage examines hypothesized relationships using path coefficients, coefficient of determination (R^2), effect size (f^2), and predictive relevance (Q^2). Bootstrapping is applied to test the significance of path coefficients.

Ethical Considerations

Participation in the study is voluntary, and respondents are informed about the research objectives prior to data collection. Confidentiality and anonymity of respondents are assured, and collected data are used solely for academic research purposes.

Methodological Contribution

By integrating big data analytics capability, demand forecasting accuracy, and supply chain performance within a single empirical model, this methodology contributes to the literature on digital transformation in perishable agribusiness. The approach provides practical insights for mushroom supply chain stakeholders seeking to leverage data-driven forecasting to enhance operational efficiency and sustainability.

RESULTS AND DISCUSSION

Measurement Model Evaluation

The measurement model was evaluated to assess the reliability and validity of the constructs. All indicator loadings exceeded the recommended threshold of 0.70, indicating strong convergent validity. Composite reliability and Cronbach's alpha values for all constructs were above 0.70, confirming internal consistency reliability. In addition, the average variance extracted (AVE) values for big data analytics capability, demand forecasting accuracy, and supply chain performance were all greater than 0.50, demonstrating adequate convergent validity.

Discriminant validity was confirmed using the Fornell–Larcker criterion, where the square root of AVE for each construct exceeded its correlations with other constructs. These results indicate that the measurement model is robust and suitable for structural model analysis.

Structural Model Evaluation

The structural model analysis reveals that big data analytics capability has a significant positive effect on demand forecasting accuracy. The path coefficient is positive and statistically significant, supporting the hypothesis that organizations with stronger analytics capabilities are better able to generate accurate and timely demand forecasts for mushroom products.

Furthermore, demand forecasting accuracy has a significant positive effect on supply chain performance. Improved forecasting accuracy contributes to better inventory management, reduced product spoilage, improved order fulfillment, and enhanced operational efficiency within the mushroom supply chain.

The direct effect of big data analytics capability on supply chain performance is also positive and significant, suggesting that analytics capabilities contribute to performance improvement not only through forecasting accuracy but also through broader data-driven decision-making processes.

The coefficient of determination (R^2) values indicate that big data analytics capability explains a substantial proportion of the variance in demand forecasting accuracy, while the combined effects of big data analytics capability and forecasting accuracy explain a meaningful proportion of supply chain performance variance. This demonstrates the strong explanatory power of the proposed model.

Mediation analysis further shows that demand forecasting accuracy partially mediates the relationship between big data analytics capability and supply chain performance. This finding indicates that while big data analytics directly enhances supply chain outcomes, its impact is significantly strengthened through improved demand forecasting.

Discussion

The findings of this study provide empirical evidence that big data analytics capability plays a crucial role in enhancing demand forecasting accuracy in the mushroom supply chain. This result aligns with Information Processing Theory, which suggests that organizations operating in uncertain environments require high information-processing capacity to improve decision quality. Given the perishability and demand volatility of mushrooms, advanced analytics enables firms to process complex demand signals more effectively than traditional forecasting approaches.

The significant relationship between demand forecasting accuracy and supply chain performance supports Supply Chain Integration Theory, emphasizing the importance of accurate information sharing and coordination among supply chain actors. Accurate forecasts allow mushroom producers and distributors to align production schedules with market demand, reduce excess inventory, and minimize post-harvest losses. This is particularly critical in mushroom supply chains, where even minor forecasting errors can lead to substantial economic losses due to spoilage.

The direct impact of big data analytics capability on supply chain performance confirms the relevance of the Resource-Based View (RBV). Big data analytics capability represents a valuable and difficult-to-imitate organizational resource that enhances operational efficiency and competitive advantage. Firms with superior analytics capabilities are better positioned to optimize pricing, logistics, and resource allocation beyond forecasting activities alone.

The partial mediating role of demand forecasting accuracy highlights the importance of forecasting as a strategic mechanism through which analytics capabilities translate into performance outcomes. This finding is consistent with Dynamic Capability Theory, which emphasizes a firm's ability to sense and respond to environmental changes. Big data analytics enables mushroom supply chain actors to continuously update forecasts based on real-time data, thereby improving responsiveness and resilience in dynamic market conditions.

From a managerial perspective, the results suggest that investment in big data analytics should not be limited to technological infrastructure alone. Developing analytical skills (Suhardjo et al., 2023), improving data quality, and fostering a data-driven culture are equally important for enhancing forecasting accuracy and supply chain performance. For policymakers and industry associations, these findings underscore the need to support digital capability development among mushroom SMEs to improve supply chain efficiency and sustainability.

CONCLUSION

Conclusion

This study investigates the role of big data analytics capability in enhancing demand forecasting accuracy and supply chain performance within the mushroom industry. The empirical findings demonstrate that big data analytics capability has a significant positive effect on demand forecasting accuracy, confirming that organizations equipped with advanced data processing and analytical capabilities are better able to predict market demand for perishable mushroom products. Accurate demand forecasting, in turn, significantly improves supply chain performance by reducing inventory inefficiencies, minimizing product spoilage, and enhancing operational responsiveness.

Moreover, the results reveal that big data analytics capability directly contributes to improved supply chain performance, highlighting its strategic value beyond forecasting functions alone. The mediating role of demand forecasting accuracy further indicates that forecasting acts as a critical mechanism through which analytics capabilities are translated into superior supply chain outcomes. Collectively, these findings underscore the importance of data-driven decision-making in managing the complexity and uncertainty inherent in mushroom supply chains.

The study contributes to the literature by extending the application of big data analytics and demand forecasting theories to a perishable agribusiness context that has received limited scholarly attention. By integrating perspectives from resource-based view, dynamic capability theory, information processing theory, and supply chain integration, this research provides a comprehensive understanding of how analytics capabilities enhance supply chain performance in the mushroom industry.

Implications

Theoretically, this study extends the literature on big data analytics and demand forecasting by providing empirical evidence from a perishable agribusiness context that has been largely overlooked. It integrates multiple grand theories to explain how analytics-driven forecasting enhances supply chain performance. Practically, the findings offer actionable insights for mushroom supply chain stakeholders. By leveraging big data analytics, firms can improve demand forecasting accuracy, reduce waste, optimize inventory, and enhance overall business performance, contributing to a more sustainable and competitive mushroom industry.

Limitations

Despite its contributions, this study has several limitations. First, the research relies on cross-sectional survey data, which restricts the ability to capture dynamic changes in analytics capability and forecasting performance over time. Second, the measurement of demand forecasting accuracy is based on perceptual assessments rather than objective forecasting error metrics, which may introduce respondent bias. Third, the study focuses primarily on mushroom supply chain actors in a specific regional context, limiting the generalizability of the findings to other agricultural sectors or geographic settings. Finally, this study does not explicitly differentiate between types of analytical tools or machine learning models used, which may vary in effectiveness across organizations.

Recommendations

Based on the findings, several practical recommendations are proposed. Mushroom supply chain stakeholders should invest in developing comprehensive big data analytics capabilities, including data integration systems, advanced analytical tools, and skilled human resources. Emphasis should be placed on improving demand forecasting processes by incorporating multiple data sources such as sales history, weather data, and market trends to enhance prediction accuracy.

Managers are also encouraged to foster a data-driven organizational culture that supports evidence-based decision-making across supply chain functions. For policymakers and industry associations, initiatives aimed at improving digital literacy and providing technological support for mushroom SMEs can help accelerate analytics adoption and improve overall supply chain efficiency. Additionally, collaborative data-sharing platforms among supply chain partners may enhance forecasting accuracy and coordination.

Future Research

Future research can extend this study in several directions. Longitudinal research designs may be employed to examine how the impact of big data analytics on demand forecasting and supply chain performance evolves over time. Researchers may also incorporate objective performance indicators, such as forecast error rates and inventory turnover ratios, to complement perceptual measures.

Further studies could explore the role of specific advanced analytics techniques, including machine learning and artificial intelligence models, in improving demand forecasting accuracy within mushroom supply chains. Comparative studies across different perishable agricultural products or across developed and emerging economies would enhance the generalizability of findings. Finally, future research may investigate moderating factors such as organizational size (Renaldo & Murwaningsari, 2023), technological readiness, and environmental uncertainty to better understand the contextual conditions under which big data analytics delivers the greatest value.

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