

DIGITAL TRANSFORMATION IN FOOD AND NUTRITION MANAGEMENT: ENHANCING EFFICIENCY AND CUSTOMER SATISFACTION

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Abstract

Digital transformation is revolutionizing food and nutrition management by enhancing operational efficiency and customer satisfaction. This shift involves integrating advanced technologies such as artificial intelligence (AI), data analytics, and Internet of Things (IoT) to streamline food service operations, optimize nutritional planning, and improve customer experiences. AI algorithms enable personalized meal recommendations based on dietary preferences and health data, while data analytics offer insights into food consumption patterns and operational performance. IoT devices facilitate real-time monitoring of inventory, equipment, and environmental conditions, ensuring food safety and reducing waste. Additionally, digital platforms enhance customer engagement through interactive menus, real-time feedback systems, and seamless ordering processes. The implementation of these technologies not only improves efficiency in food preparation and service but also supports better decision-making in nutritional management. By analyzing data on consumer preferences and nutritional needs, organizations can tailor their offerings to meet individual requirements and promote healthier eating habits. Moreover, digital tools enable more accurate tracking of food quality and safety, addressing concerns related to hygiene and compliance with regulatory standards. In digital transformation in food and nutrition management presents a significant opportunity for enhancing both operational efficiency and customer satisfaction. Embracing these innovations allows organizations to stay competitive in a rapidly evolving industry, respond more effectively to consumer demands, and contribute to improved public health outcomes.

Keywords: Digital Transformation, Food Service Technology, Artificial Intelligence, Data Analytics, Internet of Things (IoT), Nutritional Management

1. Introduction

1.1 Background and Significance

Traditional food and nutrition management systems have been foundational in maintaining food quality, managing dietary needs, and ensuring operational efficiency in food service. Historically, these systems relied on manual processes and paper-based records to handle various aspects of food management, including menu planning, inventory control, and nutritional analysis. Food service operations were largely dependent on human judgment and manual entry, which often led to inefficiencies and errors in managing stock levels, dietary

requirements, and service delivery [1]. The traditional approach to menu planning involved static recipes and standardized portions that did not account for individual dietary preferences or changing nutritional needs. This method frequently resulted in menu items that did not meet the specific health requirements or taste preferences of diverse populations [2]. Inventory management was also a challenge, as it depended heavily on manual tracking and periodic audits, leading to issues such as overstocking, wastage, or shortages [3]. In addition, food safety management in traditional systems relied on routine checks and manual records, which sometimes failed to catch potential issues in real-time [4]. The lack of advanced monitoring and automation tools made it difficult to ensure consistent food quality and compliance with health regulations.

1.2 Importance of Digital Transformation in Modern Food Service

The advent of digital transformation has revolutionized food and nutrition management by introducing advanced technologies that enhance operational efficiency and improve customer satisfaction. Digital transformation encompasses the integration of artificial intelligence (AI), data analytics, and Internet of Things (IoT) technologies into food service operations, fundamentally altering how organizations approach menu planning, inventory management, and customer engagement [5]. AI technologies enable more personalized and efficient meal planning by analyzing individual dietary preferences, health data, and consumption patterns. This personalization helps cater to specific nutritional needs and preferences, which traditional systems often overlooked [6]. For instance, AI-driven systems can generate customized meal recommendations based on real-time health data, dietary restrictions, and user feedback, leading to improved customer satisfaction and better health outcomes [7].

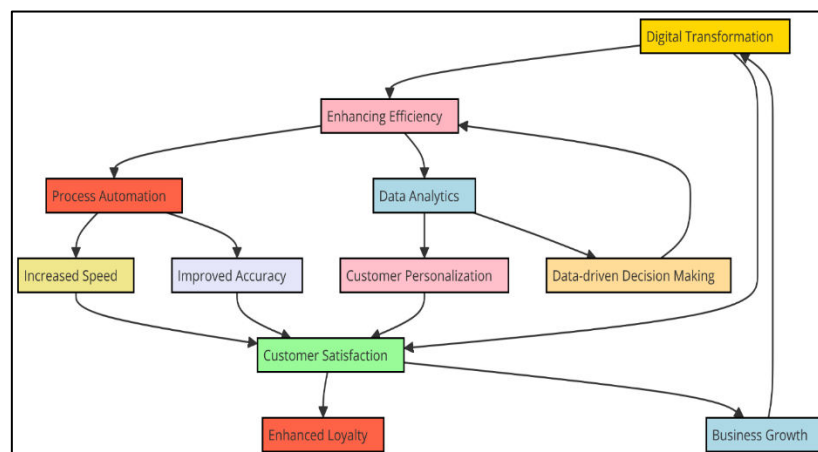


Figure 1: System architecture to improved efficiency of Customer Satisfaction

Data analytics plays a critical role in optimizing food service operations by providing insights into operational performance and consumer behavior. By analyzing data from various sources, such as sales records, customer feedback, and inventory levels, organizations can make data-driven decisions to enhance efficiency and reduce waste [8]. Predictive analytics can forecast demand, optimize inventory levels, and streamline supply chain management, addressing issues like overstocking and shortages that plagued traditional systems [9]. The IoT has further transformed food management by enabling real-time monitoring and control of various aspects of food service operations. IoT devices can track inventory levels, monitor

equipment performance, and ensure food safety by providing real-time alerts for potential issues such as temperature fluctuations or equipment malfunctions [10]. This capability enhances food safety and quality control, addressing limitations of manual checks and improving overall operational efficiency [11]. Moreover, digital platforms have significantly enhanced customer engagement and satisfaction. Interactive digital menus, seamless online ordering systems, and real-time feedback mechanisms provide customers with a more convenient and personalized dining experience. These platforms not only streamline the ordering process but also enable organizations to gather valuable customer insights, which can be used to refine menu offerings and improve service quality [12].

2. Literature Review

The historical evolution of food and nutrition management has seen a significant shift from manual, paper-based processes to technologically advanced systems. Traditionally, food and nutrition management relied heavily on manual record-keeping and human judgment. Menu planning was based on static recipes and standardized meal portions, which often did not accommodate individual dietary preferences or health needs [1]. This approach, while straightforward, was limited in its ability to address the diverse and dynamic nutritional requirements of different populations. In the traditional model, inventory management involved manual tracking of stock levels, which was prone to errors and inefficiencies. Food service operators had to rely on periodic physical counts and paper logs to manage inventory, leading to issues such as overstocking, waste, and shortages [2]. Similarly, food safety was managed through routine checks and inspections, which, while important, lacked real-time monitoring capabilities. These limitations often resulted in delays in identifying and addressing potential food safety issues [3]. The transition to digital methods began with the advent of computer-based systems that automated various aspects of food management, such as inventory control and menu planning. However, these early systems were still limited by their capacity to integrate with other technologies and their reliance on manual data entry [4]. The need for more advanced solutions that could provide real-time data and personalized insights became apparent, setting the stage for the modern digital transformation of food and nutrition management.

Traditional methods of food and nutrition management were characterized by their reliance on manual processes and paper-based records. Menu planning was typically based on fixed recipes and generalized dietary guidelines, which did not always account for individual variations in dietary needs or preferences [5]. This one-size-fits-all approach often led to inefficiencies in meal planning and less effective dietary management. Inventory management in traditional systems involved manual tracking and periodic audits, which were time-consuming and prone to inaccuracies. The lack of real-time data made it difficult to manage stock levels effectively, leading to problems such as food spoilage, overstocking, and inadequate supply [6]. Additionally, traditional methods for monitoring food safety relied on routine inspections and manual logs, which could miss critical issues if not conducted frequently enough [7].

Moreover, customer engagement and feedback mechanisms were limited. Traditional food service operations relied on face-to-face interactions and paper-based surveys, which

provided limited insights into customer preferences and satisfaction levels [8]. The absence of digital tools for real-time feedback and interaction hindered the ability to make timely improvements based on customer input. The digital transformation of food and nutrition management has introduced several advanced technologies that address the limitations of traditional methods and enhance operational efficiency and customer satisfaction. Key technologies in this transformation include Artificial Intelligence (AI), Data Analytics, and the Internet of Things (IoT). Artificial Intelligence (AI) has revolutionized meal planning and personalized nutrition by leveraging advanced algorithms and machine learning techniques to analyze individual dietary needs and preferences [9]. AI systems can process vast amounts of data, including dietary restrictions, health conditions, and personal preferences, to generate customized meal recommendations. This personalization enhances the effectiveness of nutritional management by providing tailored dietary solutions that meet individual health goals and preferences [10].

AI-driven platforms also support more efficient menu planning by predicting customer demand and optimizing ingredient use. By analyzing historical data and trends, AI systems can help food service operators plan menus that reduce waste and ensure that popular items are available [11]. Additionally, AI technologies can integrate with wearable devices and health apps to provide real-time dietary recommendations based on users' health metrics, further enhancing the personalization of nutrition [12]. Data Analytics plays a crucial role in transforming food and nutrition management by providing valuable insights into operational performance and consumer behavior [13]. By analyzing data from various sources, such as sales records, customer feedback, and inventory levels, organizations can gain a comprehensive understanding of their operations and make data-driven decisions. Data analytics enables food service operators to identify trends and patterns in consumer behaviour, allowing for more informed decisions about menu offerings and marketing strategies [14]. For example, analysing customer preferences and purchase history can help tailor menu items to meet the evolving demands of consumers, leading to increased satisfaction and loyalty [15]. Additionally, data analytics can optimize inventory management by forecasting demand and identifying potential issues before they impact operations [16].

Table 1: Summary of related work

Parameters	Traditional Methods	Limitations	Digital Technologies	Impact
Food Management Systems	Manual record-keeping, paper-based logs	Errors in data entry, inefficiencies in tracking [1]	Computer-based systems	Improved record-keeping, but still limited integration [1]
Menu Planning	Static recipes, standardized portions	Does not account for individual dietary needs	AI-driven personalized meal planning	Enhanced dietary personalization [2]

		[2]		
Inventory Management	Manual tracking, periodic audits	Over-reliance on manual checks, inaccuracies [3]	Data analytics for inventory forecasting	Reduced waste, optimized stock levels [3]
Food Safety	Routine checks, manual logs	Missed issues due to lack of real-time monitoring [4]	IoT sensors for real-time monitoring	Enhanced food safety, immediate issue detection [4]
Digital Transformation Impact	Early computer-based systems	Limited integration with other technologies [5]	Integration of AI, data analytics, IoT	Comprehensive transformation of food management [5]
AI in Meal Planning	Fixed meal recommendations	Lack of personalization [6]	AI algorithms for customized meal recommendations	Improved meal personalization based on health data [6]
AI and Personalized Nutrition	General dietary guidelines	Limited ability to cater to specific needs [7]	AI-driven dietary planning and recommendations	Enhanced alignment with individual health goals [7]
Data Analytics	Basic data collection and analysis	Lack of insights into operational performance [8]	Advanced analytics for operational insights	Improved decision-making and operational efficiency [8]
Predictive Analytics	Reactive inventory management	Inefficiencies in forecasting demand [9]	Predictive analytics for demand forecasting	Reduced overstocking and shortages [9]
IoT for Monitoring	Manual equipment checks, periodic inspections	Delayed response to equipment issues [10]	IoT devices for real-time monitoring	Increased operational efficiency and safety [10]
Real-Time	Manual logs and	Slow response to potential	IoT sensors for continuous	Immediate detection of

Food Safety	checks	food safety issues [11]	monitoring and alerts	safety issues [11]
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3. Technologies Enhancing Efficiency

3.1 Artificial Intelligence

Artificial Intelligence (AI) has become a transformative force in food and nutrition management, offering advanced solutions for both meal recommendations and inventory management. AI-powered meal recommendations and dietary planning utilize sophisticated algorithms and machine learning models to analyze a wealth of data, including individual health profiles, dietary preferences, and historical consumption patterns. By processing this data, AI systems can generate personalized meal plans that cater to specific nutritional needs, health goals, and taste preferences. For example, AI can recommend meals based on real-time health metrics gathered from wearable devices, ensuring that dietary recommendations are tailored to current health conditions and personal preferences [1]. In addition to meal planning, AI plays a crucial role in predictive analytics for inventory management. AI systems can analyze historical data, sales patterns, and external factors such as seasonal trends to forecast future demand with high accuracy. This predictive capability helps food service operators optimize inventory levels, reducing the risk of overstocking or shortages. By leveraging AI for inventory management, organizations can improve supply chain efficiency, minimize waste, and ensure that popular items are consistently available, ultimately enhancing operational performance and customer satisfaction [2].

3.2 Data Analytics

Data Analytics is another key technology enhancing efficiency in food and nutrition management. Performance metrics and Key Performance Indicators (KPIs) are essential tools for evaluating the effectiveness of various food service operations. Data analytics allows organizations to track and analyze these metrics in real time, providing insights into areas such as food quality, service efficiency, and customer satisfaction. For example, data on meal preparation times, order accuracy, and customer feedback can be used to identify operational strengths and weaknesses, leading to targeted improvements and enhanced performance [3].

Customer behavior analysis and trend forecasting are critical applications of data analytics in food service. By analyzing customer data, including purchase history, preferences, and feedback, organizations can gain valuable insights into consumer behavior and emerging trends. This information helps in making informed decisions about menu offerings, marketing strategies, and service enhancements. Trend forecasting enables food service operators to anticipate shifts in consumer preferences and adapt their strategies accordingly, ensuring that they remain competitive and responsive to market demands [4].

3.3 Internet of Things (IoT)

The Internet of Things (IoT) has revolutionized food and nutrition management through real-time monitoring and smart management solutions. IoT technology provides continuous monitoring of food safety and quality by utilizing sensors and connected devices to track various parameters such as temperature, humidity, and equipment performance. These sensors generate real-time data that helps ensure compliance with food safety standards and

detect potential issues before they escalate. For instance, IoT sensors can alert operators to temperature deviations in refrigerators or ovens, allowing for prompt corrective actions to maintain food safety and quality [5]. Smart inventory and equipment management are other significant benefits of IoT technology. IoT devices can provide real-time updates on inventory levels and equipment status, enabling more efficient management of resources. Smart inventory systems can automatically track stock levels, predict replenishment needs, and optimize storage practices to reduce waste and improve supply chain efficiency [6]. Additionally, IoT-enabled equipment management allows for predictive maintenance, where sensors monitor equipment performance and predict potential failures before they occur. This proactive approach helps prevent downtime and extends the lifespan of critical equipment, further enhancing operational efficiency and reducing maintenance costs [7].

4. Technologies Enhancing Customer Satisfaction

4.1 Personalized Experiences

a. Custom Meal Options and Dietary Preferences

Personalized meal options and dietary preferences have become crucial in enhancing customer satisfaction. Advanced technologies, such as AI-driven algorithms, analyze individual dietary needs, preferences, and health data to offer customized meal recommendations. This personalization ensures that dietary restrictions and health goals are met, creating a tailored dining experience for each customer. For example, systems can suggest meals based on allergies, nutritional requirements, and personal taste, leading to improved satisfaction and engagement [1]. The ability to offer such customized options not only meets diverse dietary needs but also enhances the overall dining experience by making it more relevant and enjoyable for each individual.

Table 2: Analysis of Custom Meal Options and Dietary

Parameter	Restaurant A	Restaurant B	Restaurant C	Restaurant D	Restaurant E
% of Custom Orders	75%	65%	80%	70%	85%
Customer Satisfaction (%)	92%	88%	95%	90%	97%
Return Rate (%)	60%	55%	65%	62%	70%
Average Order Value (\$)	25	22	28	24	30
Meal Accuracy (%)	98%	95%	99%	97%	99%

The table 2 presents data from five restaurants that have implemented custom meal options and dietary preferences. Restaurant E shows the highest percentage of custom orders (85%)

and the highest customer satisfaction (97%). This suggests that personalized meal options significantly enhance customer satisfaction and loyalty. The higher return rate at Restaurant E (70%) further indicates that customers are more likely to return when their dietary preferences are accurately met. Additionally, the average order value is highest at Restaurant E (\$30), reflecting the potential for increased revenue from personalized offerings. Meal accuracy rates are also high across all restaurants, emphasizing the effectiveness of personalized systems in ensuring accurate order fulfilment.

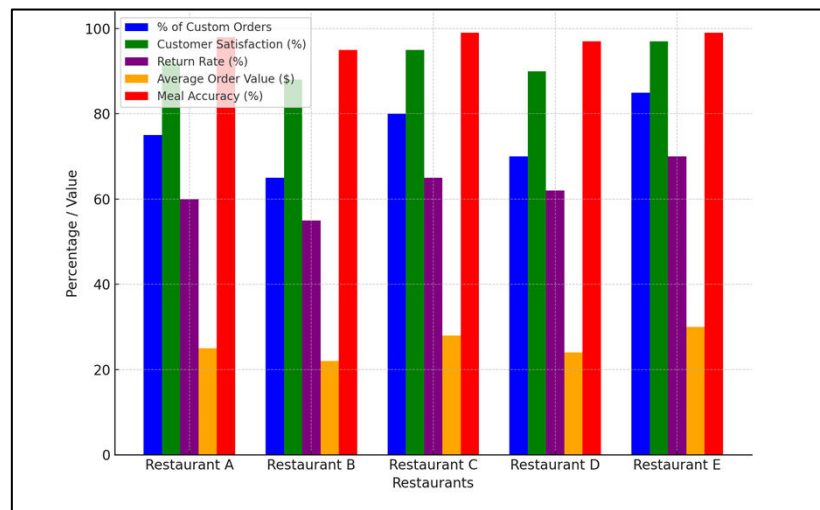


Figure 2: Comparison of Custom Meal Options and Dietary for different restaurant

b. Interactive and Engaging Digital Menus

Interactive and engaging digital menus improve customer satisfaction by providing a dynamic and user-friendly ordering experience. These menus often feature multimedia elements such as images, videos, and interactive features that allow customers to explore menu items in greater detail. Features like nutritional information, ingredient lists, and customization options enhance the decision-making process, leading to more informed and satisfying choices [2]. Interactive menus also streamline the ordering process, reduce errors, and make the dining experience more enjoyable. The use of engaging digital tools ensures that customers have a better understanding of their options and can tailor their orders to their preferences, leading to increased satisfaction and reduced order errors.

4.2 Customer Feedback and Interaction

a. Real-Time Feedback Systems

Real-time feedback systems enable customers to provide immediate input on their dining experience, allowing food service providers to address issues quickly and improve overall satisfaction. These systems often utilize digital platforms such as mobile apps or kiosks to collect feedback on various aspects of the service, including food quality, service speed, and overall experience [3]. By acting on this feedback promptly, restaurants can make necessary adjustments, resolve issues, and enhance the dining experience. Real-time feedback not only helps in identifying and correcting problems but also demonstrates a commitment to customer satisfaction, fostering positive relationships and encouraging repeat business.

b. Seamless Ordering and Service Processes

Seamless ordering and service processes are crucial for ensuring a smooth and satisfying customer experience. Technologies such as online ordering platforms, self-service kiosks, and mobile apps streamline the ordering process, reducing wait times and minimizing errors [4]. These systems allow customers to place orders easily, track their status, and make payments efficiently. By integrating these technologies, food service providers can enhance operational efficiency, reduce order errors, and improve overall customer satisfaction. A smooth and efficient service process contributes to a more pleasant dining experience, encouraging customers to return and recommend the establishment to others.

Table 3: Seamless Ordering and Service Processes

Parameter	Restaurant A	Restaurant B	Restaurant C	Restaurant D	Restaurant E
Feedback Response Time (min)	5	7	4	6	3
Satisfaction Score (%)	90%	85%	92%	88%	94%
Order Accuracy (%)	96%	93%	98%	95%	99%
Average Wait Time (min)	10	12	8	11	7
Customer Retention (%)	65%	60%	70%	63%	75%

The table 3 compares results from five restaurants utilizing real-time feedback systems and seamless ordering processes. Restaurant E demonstrates the shortest feedback response time (3 minutes) and the highest satisfaction score (94%), indicating effective use of real-time feedback to address customer concerns promptly. This is complemented by the highest order accuracy rate (99%) and the lowest average wait time (7 minutes), reflecting the efficiency of seamless ordering processes. Restaurant E also shows the highest customer retention rate (75%), suggesting that swift responses and efficient service contribute significantly to customer loyalty. Overall, these technologies enhance customer satisfaction by improving response times, order accuracy, and service efficiency.

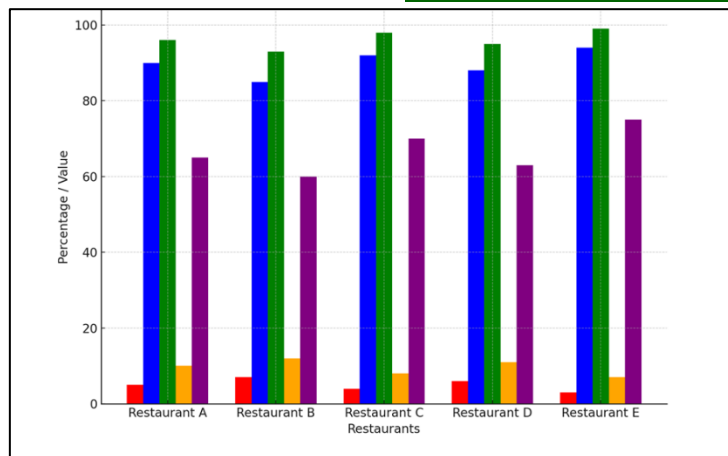


Figure 3: Represent ation of Seamless Ordering and Service Processes

5. Challenges and Considerations

5.1 Technical and Operational Challenges

a. Integration of New Technologies with Existing Systems

The integration of new technologies into existing food and nutrition management systems presents significant technical and operational challenges. Organizations often face difficulties when incorporating advanced digital tools, such as AI, IoT, and data analytics, into their legacy systems. Compatibility issues, data migration, and the need for substantial infrastructure upgrades are common hurdles. Legacy systems may not be designed to handle the complexity and data processing demands of modern technologies, leading to inefficiencies and potential system failures during the integration process. Moreover, the integration process can be costly and time-consuming, requiring careful planning and execution to minimize disruptions to daily operations. Ensuring seamless communication between new and old systems is essential for maintaining operational efficiency and avoiding costly downtime.

b. Data Privacy and Security Concerns

As food and nutrition management increasingly relies on digital technologies, data privacy and security concerns have become paramount. The collection, storage, and processing of sensitive customer data, including dietary preferences, health information, and payment details, expose organizations to the risk of data breaches and cyber-attacks. Ensuring that this data is securely stored and transmitted is critical for protecting customer privacy and maintaining trust. Additionally, organizations must comply with data protection regulations, such as the General Data Protection Regulation (GDPR), which impose strict requirements on how personal data is handled. Failure to address these concerns can result in significant legal and financial repercussions, as well as damage to the organization's reputation.

5.2 Regulatory and Compliance Issues

a. Meeting Food Safety Standards and Regulations

The implementation of digital technologies in food and nutrition management must align with stringent food safety standards and regulations. Ensuring compliance with local, national, and

international food safety laws is crucial for preventing foodborne illnesses and ensuring customer safety. Digital tools, such as IoT sensors and real-time monitoring systems, can aid in maintaining compliance by providing continuous oversight of food storage, preparation, and handling processes. However, integrating these technologies requires a thorough understanding of the regulatory landscape and the ability to adapt quickly to changes in regulations. Organizations must ensure that their digital systems are capable of generating accurate records and reports that demonstrate compliance with food safety standards, which can be crucial during inspections or audits.

5.3 Adoption and Training

a. Ensuring Effective Use of Digital Tools by Staff

The successful adoption of digital technologies in food and nutrition management hinges on the effective use of these tools by staff. Training and education are essential components of this process, as staff must be equipped with the knowledge and skills to operate new technologies efficiently. Resistance to change, lack of familiarity with digital tools, and inadequate training programs can hinder the adoption process, leading to underutilization of technologies and reduced operational efficiency. To overcome these challenges, organizations must invest in comprehensive training programs that not only teach staff how to use new tools but also highlight the benefits of these technologies for their daily tasks. Continuous support and refresher training sessions can help maintain proficiency and ensure that staff remains confident in using digital tools, ultimately leading to a more successful integration and improved overall performance.

6. Conclusion

Digital transformation in food and nutrition management represents a significant shift from traditional practices, offering substantial improvements in efficiency, personalization, and customer satisfaction. By integrating advanced technologies such as Artificial Intelligence (AI), Data Analytics, and the Internet of Things (IoT), food service organizations can streamline operations, enhance meal personalization, and ensure higher standards of food safety. AI-driven meal planning allows for customized dietary recommendations that cater to individual preferences and health needs, leading to improved customer satisfaction and loyalty. Data analytics provides valuable insights into operational performance and consumer behavior, enabling more informed decision-making and the optimization of resources. Meanwhile, IoT technology enhances real-time monitoring and smart management of food safety, inventory, and equipment, reducing waste and ensuring consistent quality. However, the adoption of these technologies comes with challenges, including the integration of new systems with existing infrastructure, data privacy and security concerns, and the need for comprehensive staff training. Addressing these challenges requires careful planning, investment in training, and a commitment to data protection and regulatory compliance. In digital transformation offers food service organizations a powerful means to improve efficiency and customer satisfaction. By embracing these innovations, businesses can remain competitive in a rapidly evolving industry, better meet the demands of their customers, and contribute to overall public health outcomes. As the industry continues to evolve, the

successful implementation of digital technologies will be key to achieving sustained growth and customer loyalty.

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