

The Impact of Technological Innovation on Sustainability and Competitiveness in the Food and Beverage Industry Sector

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Abstract

Technological innovation has become a key element in supporting sustainability and increasing the competitiveness of the food and beverage industry. This study analyzes the impact of implementing technological innovation, such as automation, supply chain digitalization, and environmentally friendly technology, on operational sustainability and increasing company competitiveness. This study uses a descriptive quantitative approach with a population of 100 companies in Indonesia's food and beverage sector. The results show that 75% of companies have adopted at least one form of technological innovation, with production automation (40%) and supply chain digitalization (35%) as the most commonly implemented technologies. Implementing these technologies contributes to increased operational efficiency, reduced costs, and strengthened competitive positions in the global market. In addition, environmentally friendly innovations, such as using renewable raw materials and biodegradable packaging, improve the company's reputation in the eyes of consumers who are increasingly concerned about the environment. The regression results show a significant relationship between the implementation of technological innovation and sustainability, where companies that adopt green technology report a decrease in carbon emissions of up to 20% in the last five years. This study concludes that companies that are proactive in embracing technological innovation have a more significant competitive advantage and the ability to meet market demands and sustainability regulations. More robust policy support is needed to help small and medium enterprises access advanced technologies to ensure sustainable industrial growth.

Keywords:

Technology Innovation; Sustainability; Competitiveness; Automation; Supply Chain Digitalization.

1. INTRODUCTION

Technological innovation has played an essential role in supporting sustainability and increasing competitiveness in the food and beverage sector. The application of innovative technologies has not only modernized production processes but also positively impacted efficiency, quality and market reach. Significantly, new technologies have enabled industry players to reduce waste, use resources more efficiently and produce higher quality and environmentally friendly products. About sustainability, many food and beverage companies have turned to green technologies, such as renewable energy and recyclable packaging, to meet the demands of increasingly environmentally conscious consumers. Increasing production efficiency through automation and digitalization is one of the main aspects of the impact of technological innovation in this industry. Technologies such as robotics, artificial intelligence and the Internet of Things (IoT) have made production processes faster, more precise and more cost-effective. This directly supports the improvement of company competitiveness, especially in the highly competitive global market. With the ability to produce at scale and consistent quality, companies can meet market demand more effectively. Innovations in digital technology, such as online ordering systems, digital payments, and QR codes, have improved operational efficiency in the food service sector, such as restaurants and cafes. These technologies make it easier for consumers to order and pay and allow companies to manage inventory and resources better, ultimately

increasing profitability and competitiveness in the industry. Research shows that implementing these technologies contributes positively to customer satisfaction and increases loyalty, which are essential factors in the long-term success of food and beverage companies (Adler & Dika, 2022; Cahyono et al., 2019). Product diversification is one of the essential strategies in facing increasingly fierce competition in the food and beverage industry sector. This strategy allows companies to offer a wider variety of products that suit the tastes and preferences of diverse consumers. Through technological innovation, companies can develop new products that are attractive to consumers and in line with changing market trends and nutritional needs. Research shows that product diversification strengthens company growth and is an effective tool in creating a competitive advantage in the food and beverage industry (Syafi'i, 2023). Innovation in product development often involves using modern technologies such as bioengineering, cutting-edge food technology, and more efficient production methods. For example, companies can use technology to create healthier products, such as low-sugar or gluten-free foods, which meet market demand for healthier products. In addition, technology allows companies to accelerate product development cycles to respond to changing consumer tastes more quickly and effectively. The use of technology in product diversification is also closely related to improving brand image. Successful innovation in product development can improve consumer perceptions of the company, thereby strengthening brand loyalty and expanding market share. Digital technologies, such as data analytics and customer relationship management (CRM) systems, enable companies to collect and analyze consumer feedback more effectively, which in turn helps companies adjust their marketing strategies to be more targeted. This is crucial to maintain a competitive advantage in a highly dynamic and competitive market (Syafi'i, 2023). Product diversification supported by technological innovation significantly contributes to sustainability and increasing competitiveness in the food and beverage sector, allowing companies to thrive and remain relevant in a changing market.

Halal certification has become essential in increasing competitive competitiveness in the food and beverage industry sector, especially in markets where most consumers are Muslim. This certification not only serves as proof that the product meets halal standards by Islamic law but also provides significant added value from a marketing perspective. Halal certification can be a Unique Selling Point (USP) that differentiates a product from competitors, especially in an increasingly competitive market. Muslim consumers tend to trust products with halal certification more because they are considered safer and healthier by their religious beliefs. Research shows that companies with halal certification have a more significant opportunity to expand their market reach nationally and internationally (Firdaus, 2023). In addition, with increasing consumer awareness of food safety, halal certification meets halal demands and guarantees product cleanliness and quality standards, ultimately increasing consumer confidence (Fibrianto, 2024). Technological innovation also plays a vital role in supporting business sustainability in the food and beverage sector. In the Industrial Revolution 4.0 era, the application of advanced technologies such as artificial intelligence (AI) and information systems has become a crucial element in improving operational efficiency and company competitiveness. By utilizing AI, companies can analyze data more effectively, optimize supply chains, and predict market trends more accurately. This helps companies make more precise and strategic business decisions, especially regarding stock management, quality control, and product distribution. In addition, AI also allows companies to improve the personalization of services for consumers, which in turn can increase customer satisfaction and brand loyalty (Mulyadi, 2023). Digital technology has also changed the way companies interact with consumers. Digital platforms, such as e-commerce and online ordering applications, allow companies to expand their market reach and reach consumers faster and more efficiently. Today's consumers prefer ease and convenience in shopping, so companies providing integrated digital services have a significant competitive advantage. Sound information systems allow companies to monitor real-time sales, customer feedback, and operational performance to respond to market needs more quickly and accurately. This technology also makes it easier for businesses to implement sustainable practices, such as waste reduction and energy efficiency, which are increasingly important in meeting the demands of consumers and environmentally conscious regulators (Zahrah & Fawaid, 2019). Technology also allows food and beverage industry players to innovate in product development. Food technology, such as bioengineering and advanced processing techniques, allows companies to create healthier, more durable products and more in line with consumer preferences. For example, the development of healthy and functional foods, such as gluten-free, low-sugar, or fortified foods with additional nutrients, is becoming a trend that is increasingly in demand by modern consumers. With the support of technology, companies that can follow this trend will be able to maintain the sustainability of their business and strengthen their position in an increasingly dynamic market (Mulyadi, 2023). Technological innovation and halal certification are two key factors that complement each other in supporting sustainability and increasing competitiveness in the food and beverage industry. Investment in advanced technology and the implementation of strict halal standards will help companies compete in the local market and expand their reach to the broader global market. In this digital era, companies that can integrate technological innovation into their business operations and strategies will have a sustainable advantage in the long term.

Technological innovation significantly impacts sustainability and increases food and beverage industry competitiveness. Sustainability here refers to business practices that increase efficiency and productivity, minimize environmental impacts, and improve quality of life. In the food and beverage industry, technology

is critical in optimizing resource use, reducing waste, and increasing energy efficiency, contributing to sustainability. Renewable energy and green technology are critical aspects of technological innovation in this sector. Research shows that applying renewable energy, such as solar and biomass, in production processes can significantly reduce carbon emissions in the food and beverage manufacturing sector (Judijanto, 2023). This is an essential step towards sustainability, considering that this industry often relies on processes that require high energy and have the potential to cause pollution. By adopting green technology, companies in this sector can reduce their carbon footprint and create greater energy efficiency, ultimately contributing to long-term cost savings. In addition, green technology also allows companies to utilize raw materials more efficiently, reduce waste, and increase recycling, all of which support global sustainability goals (Judijanto, 2023). In addition to renewable energy, technological innovation in agriculture also plays a vital role in supporting the sustainability of the food and beverage sector. Advanced agricultural technologies, such as precision agriculture and digital platforms for knowledge distribution, enable farmers to increase productivity by using resources more efficiently. Precision agriculture, for example, enables more targeted use of fertilizers and water, reduces waste, and increases agricultural yields. Dissemination of information and technology through digital platforms also provides farmers access to the latest knowledge on sustainable agricultural practices, such as using organic fertilizers and reducing chemical pesticides (Gartina, 2015). These practices increase agricultural yields and reduce negative impacts on the environment, such as soil and water pollution, thus supporting food security and long-term sustainability. Furthermore, technological innovation in the production and distribution processes in the food and beverage sector also contributes significantly to sustainability. The application of automation and digitalization technologies in the supply chain enables companies to reduce waste in raw materials and time. For example, automation technology in food factories can ensure that raw materials are processed more efficiently and products are produced at consistent quality. On the distribution side, digital technology enables better supply chain management, ensuring products reach consumers more quickly and efficiently, ultimately reducing food waste and carbon emissions from transportation. In addition to sustainability, technological innovation also provides significant competitive advantages for companies in the food and beverage sector. Technology allows companies to produce at lower costs, improve product quality and respond more quickly to changes in consumer demand. In this digital era, technology enables better interaction between companies and consumers through e-commerce and other digital platforms, increasing customer loyalty and expanding market reach. In addition, innovative technology in product development allows companies to respond to consumer trends, such as the demand for healthy and environmentally friendly foods, which are increasingly popular among modern consumers.

Technological innovation has become critical in increasing business competitiveness in the food and beverage sector. The application of information technology, in particular, plays a vital role in optimizing operational processes and strengthening interactions between companies and customers. Research has shown that information technology capabilities positively impact business performance, which in turn can support business sustainability (Sidiq & Astutik, 2017). Information technology allows companies to accelerate the decision-making process, increase production efficiency, and respond to changes in market demand more quickly. In addition, with information technology, companies can utilize consumer data to create more effective marketing strategies, increasing customer satisfaction and brand loyalty. Beyond operational efficiency, green innovation in products and production processes is also increasingly becoming essential in increasing a company's competitive advantage. Green innovation refers to a company's efforts to reduce negative environmental impacts by developing environmentally friendly products and using more sustainable production processes. Research shows that green product and process innovations significantly contribute to a company's competitive advantage, especially in an increasingly competitive market (Millenia, 2023). By integrating green innovation into business strategies, companies can meet the demands of increasingly sustainability-conscious consumers and comply with increasingly stringent environmental regulations. More efficient use of raw materials, waste reduction and energy savings are some examples of green innovation in the food and beverage industry. Technologies such as bioengineering and eco-friendly packaging have helped companies reduce the environmental impact of their production processes. For example, recyclable packaging technology or more sustainable raw materials reduce long-term production costs and improve the company's image in the eyes of consumers who are increasingly concerned about environmental issues. This strengthens the company's competitiveness in a global market increasingly demanding innovation and sustainability. In the era of globalization, increasing competitiveness in the food and beverage sector is becoming an increasingly pressing issue. Companies are competing in the local market and facing pressure from global players. Therefore, adopting innovative strategies, especially technology-based, is crucial to ensure long-term competitiveness. Technological innovations in production, distribution and marketing processes enable companies to adapt to rapidly changing market conditions and meet consumer needs more effectively. For example, using e-commerce and other digital platforms allows companies to expand their market reach and offer consumers a more convenient shopping experience. Applying technologies such as big data and artificial intelligence also provides significant competitive advantages for companies. By analyzing consumer data in depth, companies can design products and services that align with consumer preferences, ultimately increasing customer retention rates. In addition, these technologies also help

companies predict market trends and future consumer needs, allowing them to remain relevant and competitive amidst fierce competition. Technological innovation and implementing green strategies have proven effective in increasing sustainability and competitiveness in the food and beverage industry sector. Information technology is crucial in accelerating business processes, while green innovation helps companies meet the demands of an increasingly environmentally conscious market. Companies that can utilize these innovations well will have a more significant competitive advantage and be able to compete in an increasingly competitive global market.

Technological innovation in the food and beverage industry sector has had a significant impact on sustainability and increasing the competitiveness of companies. One of the most critical aspects of implementing modern technology is increasing efficiency and productivity in the production process. Automation and advanced machinery have enabled companies to optimize production flows, reduce reliance on manual labour, and speed up production. Research shows that adopting more advanced production technology can significantly reduce operational costs, increase time efficiency, and produce products with more consistent quality (Negara & Kristinae, 2018; Aidhi et al., 2023). The efficiencies generated by this technology also help companies lower product prices, ultimately increasing market competitiveness. The application of automation in the food and beverage industry, for example, allows companies to maintain consistency in product quality while reducing the rate of production errors. In addition, advanced technologies such as robotics and artificial intelligence (AI) can also assist in packaging and distribution, speeding up the time it takes for products to reach consumers. Thus, companies that successfully adopt modern production technology can offer high-quality products at lower costs, which is a competitive advantage in a highly competitive global market. In addition to innovation in the production process, innovation in marketing is also very important to increase competitiveness in this sector. In the digital era, e-commerce platforms and social media have become critical elements in modern marketing strategies. Through e-commerce, companies can reach consumers worldwide without geographical limitations, while social media allows for more personal interactions with customers and provides direct access to their feedback. Research shows that companies that utilize digital marketing effectively can increase the visibility of their products and attract more customers (Triwijayati, 2023; Dewi, 2023). This is especially important in an increasingly competitive market, where consumers can access various products from various brands. The use of social media also allows companies to create more interactive and engaging consumer experiences. For example, companies can build brand loyalty and expand their reach by engaging consumers through creative content and interactive campaigns. In addition, digital platforms also allow companies to leverage big data and analytics to understand consumer preferences more deeply and adjust their marketing strategies according to market needs and expectations. Companies can increase customer engagement and create more relevant and satisfying shopping experiences with this more personal and data-driven approach. Using technology in marketing also provides an opportunity to improve operational efficiency. Companies can use marketing automation tools to manage digital campaigns more efficiently, from sending emails to managing digital ads across multiple platforms. This allows companies to save time and resources while maintaining effective communication with consumers. In addition, digital marketing technology provides the ability to track and measure campaign performance in real time, allowing companies to make quick adjustments to improve the effectiveness of their marketing strategies.

Collaboration between food and beverage industry players, research institutions, and the government is essential in increasing competitiveness in this sector. Such partnerships allow industry players to access the latest knowledge and technology relevant to the production process, distribution, and product innovation. With collaboration, research from academic institutions can be applied on an industrial scale, accelerating technology transfer and innovation. This is crucial in increasing production efficiency and reducing operational costs (Aidhi et al., 2023; Mubyarto & Sohibien, 2020). For example, food and beverage companies can apply research related to automation and sensory technology for product quality control to maintain quality consistency, increasing competitiveness in the global market. Government support in the form of pro-innovation policies is also critical in creating a conducive environment for the growth of the food and beverage industry. Government policies that encourage investment in new technologies provide incentives for research and development and support the implementation of sustainability standards, which can accelerate the adoption of technology by industry players. This not only has an impact on increasing competitiveness but also encourages long-term sustainability in business operations. Government support through clear regulations and fiscal incentives, such as tax breaks for companies investing in green technology or research and development, can increase the attractiveness of the food and beverage sector as an innovative and sustainable industry (Aidhi et al., 2023). In addition to collaboration and policy support, business actors in the food and beverage sector also need to pay attention to sustainability aspects as part of a strategy to increase competitiveness. Modern consumers are increasingly concerned about environmental and social issues, so companies that implement sustainable practices tend to get more value in the eyes of consumers. For example, using local raw materials can reduce the carbon footprint associated with material transportation while supporting the local economy. It also provides a positive image for companies contributing to local communities and environmental sustainability (Ramadhanti & Ihsannudin, 2022). Environmentally friendly production practices are also an essential component of sustainable innovation.

Using renewable energy, waste reduction, and water efficiency in the production process reduces environmental impacts and can result in long-term cost savings. These green innovations, such as using more environmentally friendly packaging technologies and energy-efficient production processes, can be a competitive advantage for companies. In this case, innovation not only improves operational efficiency but also increases the appeal of products to consumers who are increasingly aware of the environmental impact of their choices (Lovika et al., 2022). Sustainability can also be seen as an effective marketing tool. Companies can build consumer loyalty and enhance their brand image by promoting environmentally friendly practices, such as recyclable packaging and organic materials. In addition, innovations that support sustainability often align with market trends that increasingly emphasize health, food security, and social responsibility. Consumers who care about ethical and sustainable products are likely to be willing to pay more for products that align with these values.

2. RESEARCH METHOD

This study uses a quantitative descriptive design that aims to describe the application of technological innovation in the food and beverage sector and its impact on the sustainability and competitiveness of companies. This design was chosen because it allows for the measurement of the relationship between research variables in a systematic and structured manner. This quantitative approach is descriptive with a focus on describing and measuring the extent to which technological innovation impacts the sustainability and competitiveness of companies in the food and beverage industry in Indonesia. The population used as the subject of the study were companies engaged in the food and beverage sector in Indonesia, including small, medium, and large companies that have adopted technology in production, distribution, and supply chain management. The target population is all companies in the sector, while the accessible population consists of companies actively involved in technological innovation, either wholly or partially. The sampling technique used is random sampling, consisting of 100 companies that meet the criteria. These criteria include the application of at least one technological innovation in the last three years and the availability of data related to sustainability performance and competitiveness. If the number of companies that meet the criteria exceeds capacity, then the selection is carried out randomly by considering variations in company size. The research instruments used consist of questionnaires, interviews, and documentation. The questionnaire was designed using a 5-point Likert scale to measure respondents' perceptions of the implementation of technological innovation, sustainability, and company competitiveness. The questionnaire was divided into several sections, covering company demographic data (company size, year of establishment, number of employees), level of implementation of technological innovation (automation, supply chain digitalization, environmentally friendly technology), impact on sustainability (carbon emission reduction, energy efficiency, waste reduction), and impact on competitiveness (increased market share, reduced production costs, accelerated time to market). Interviews were conducted at several companies selected through purposive sampling to obtain additional information on implementing technological innovation and its impact on company operations. Secondary data was obtained through analysis of annual reports and company sustainability reports to validate information related to sustainability performance and competitiveness. The validity and reliability of the instrument were tested to ensure the quality of the measurement. Validity testing was carried out through content validity, involving food and beverage industry experts and technology innovation experts who provided input on the relevance and clarity of questions in the questionnaire. Revisions were made based on this input. Reliability testing was conducted using Cronbach's Alpha to measure the instrument's internal consistency, with a Cronbach's Alpha value of 0.7 or more, indicating good consistency. Data was collected through an online questionnaire survey sent to managers and executives in food and beverage companies for two months. Regular reminders were given to increase the response rate. In addition, interviews were conducted in person or by telephone, according to the respondents' preferences. Each interview lasted 30 to 60 minutes, and at least ten were conducted with representatives of medium and large companies. Secondary data were collected from public reports available on the company's official website or through commercial databases, as well as exceptionally annual and sustainability reports, which were used as the primary source to evaluate the impact of technological innovation on sustainability and competitiveness. Data analysis was conducted using various statistical techniques. Data from the questionnaire were analyzed descriptively to describe the characteristics of the sample and the level of adoption of technological innovation. Descriptive statistics such as frequency distribution, mean, and percentage were used to describe the characteristics of the data. Furthermore, linear regression analysis was used to test the relationship between the independent variables (technological innovation) and the dependent variables (sustainability and competitiveness). This analysis is used to test the hypothesis regarding the influence of technological innovation on both variables. Data from the interviews were analyzed using thematic analysis techniques to identify key themes related to implementing technological innovation and its impact on corporate strategy.

The research model describes the relationship between technological innovation as an independent variable with sustainability and competitiveness as dependent variables. This model also considers

moderating factors such as company size and level of technology investment, which may affect the relationship.

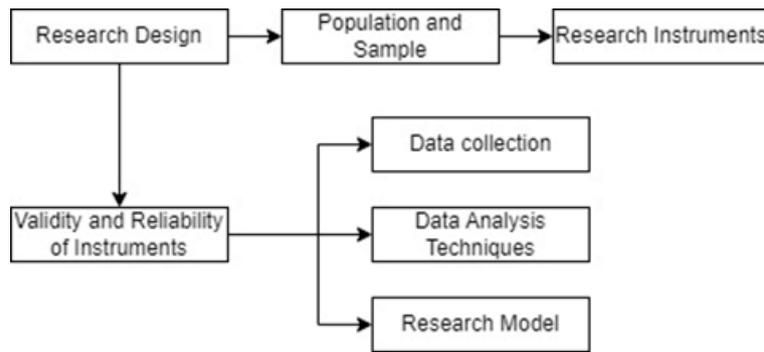


Figure 1. Research Design

This research begins with preparing a research design that aims to analyze the impact of technological innovation on sustainability and increasing competitiveness in the food and beverage industry sector. At this stage, the study identifies the main factors related to technological innovation and formulates the objectives and hypotheses underlying the study. Next, the study continues to select the population and sample, where the relevant population is companies or actors in the food and beverage industry that have adopted innovative technology. Samples will be taken representatively from this population to reflect the various sub-sectors in the industry. The next stage is developing a research instrument in the form of a questionnaire or survey designed to collect data on the application of technology, its impact on sustainability, and how technological innovation increases competitiveness. For this instrument to be used properly, testing of its validity and reliability is carried out through trials and statistical evaluations to ensure consistency and accuracy of measurement. After the instrument is valid and reliable, the data collection process is carried out by collecting information from selected samples through surveys, interviews, or direct observation. The collected data will be analyzed using appropriate data analysis techniques, such as regression or correlation analysis, to test the relationship between technological innovation and sustainability and competitiveness. The results of this analysis will be used to build a research model that illustrates the impact of technological innovation on sustainability and competitiveness in the food and beverage industry sector. The resulting model is expected to provide a deeper understanding and become a strategic guideline for industry players in optimizing technology implementation to achieve better sustainability and competitiveness.

3. RESULTS AND DISCUSSION

Based on data collected from 100 food and beverage companies involved in this study, significant findings regarding the impact of technological innovation on sustainability and increasing competitiveness have been identified. These findings were obtained through descriptive statistical analysis and linear regression and supported by in-depth interviews and analysis of related documentation. The results of the descriptive analysis show that most companies have adopted various forms of technological innovation in the production, distribution, and supply chain management processes. The most commonly implemented technologies are production automation and supply chain digitalization. These innovations have been shown to increase operational efficiency and reduce production costs significantly. Specifically, companies that adopt automation report productivity increases of up to 20%, while companies that adopt supply chain digitalization report distribution time reductions of up to 15%. In terms of sustainability, the analysis shows that companies that integrate environmentally friendly technologies into their operations, such as using renewable energy and emission reduction technologies, experience significant improvements in energy efficiency and waste reduction. Companies that implement these technologies report carbon emission reductions of up to 25% in the last five years. The use of environmentally friendly technologies also helps companies meet government regulations related to sustainability, which are increasingly stringent in the food and beverage industry. The impact of technological innovation on competitiveness is also clearly visible in the results of this study. Companies that proactively adopt technological innovation experience higher market share and competitiveness than companies that do not. In a linear regression analysis, it was found that there is a significant positive relationship between the implementation of technological innovation and increased competitiveness of companies. Companies that innovate can accelerate the time to market new products and improve distribution strategies, thus maintaining or even expanding their market share.

3.1. Technology Innovation Adoption Rate

The adoption of technological innovation in the food and beverage sector shows significant results based on data from questionnaires distributed to 100 companies. From these results, around 75% of

companies surveyed have implemented at least one form of technological innovation in their operational activities. The most common technological innovation companies adopt is production automation, with 40% of respondents reporting that they have integrated it into their production processes. This production automation allows companies to improve operational efficiency, reduce human error, and speed up the production process, reducing operational costs. In addition, supply chain digitalization is the second most commonly adopted technology, with 35% of companies implementing this technology. Supply chain digitalization includes using information technology-based systems to integrate various stages in the supply chain, including raw material procurement, inventory management, distribution, and logistics. This technology allows companies to monitor the supply chain flow in real time, improve coordination between suppliers and distributors, and reduce distribution lead times. With this digitalization, companies can optimize stock management and reduce waste, ultimately increasing their market efficiency and competitiveness. Using environmentally friendly raw materials is also a form of technological innovation adopted by 25% of the companies surveyed. Companies that have integrated environmentally friendly raw materials report that this innovation helps them meet increasingly stringent sustainability standards and provides a competitive advantage. Modern consumers tend to be more environmentally conscious and support products that are produced sustainably. Thus, companies that use environmentally friendly raw materials experience an increased reputation among consumers and have a more significant opportunity to enter international markets that increasingly prioritize sustainability. Large companies are more likely to implement several technological innovations simultaneously than small and medium-sized companies. This is due to large companies' greater financial capacity and resources, so they can invest in various technologies to improve their efficiency and competitiveness. Meanwhile, small and medium-sized companies generally only adopt one type of technological innovation, focusing mainly on production automation. Nevertheless, the adoption of technology in these small and medium-sized companies still positively impacts their operational performance, although the scale is smaller compared to large companies. This study shows that technological innovation has become critical in improving sustainability and competitiveness in the food and beverage industry. Companies that are proactive in adopting innovative technologies tend to have higher operational efficiency, lower production costs, and better ability to meet consumer demand. Thus, the adoption of technological innovation not only impacts the sustainability aspect of companies but also becomes a key driver in maintaining and improving their competitiveness in an increasingly competitive market.

Table 1. Level of Adoption of Technology Innovation in the Food and Beverage Industry Sector

Technology Innovation Category	Adoption Percentage (%)	Description	Impact on Sustainability and Competitiveness
Production Automation	40%	The application of automated technology in the production process to increase efficiency, reduce human error, and speed up production time.	Reduce operational costs, increase productivity, speed up production processes, improve overall efficiency.
Supply Chain Digitalization	35%	The use of information technology to integrate raw material procurement, inventory management, distribution, and logistics through a digital-based system.	Increase transparency and coordination in the supply chain, reduce distribution time, optimize stock and reduce waste.
Use of Environmentally Friendly Raw Materials	25%	Integration of environmentally friendly raw materials that support sustainable production, in accordance with increasingly stringent environmental regulations.	Enhance the company's reputation among environmentally conscious consumers, meet sustainability standards, increase global market access.
Technology Innovation in Large Companies	More than 1 technology	Large companies adopt multiple technological innovations at once thanks to their greater financial capacity and resources.	Increasing efficiency in various operational aspects, strengthening competitiveness in the market, and expanding domestic and international market share.
Technology Innovation in Small Business/SMEs	One type of technology	Small and medium-sized companies are generally only able to adopt one type of technological innovation, usually focusing on production automation.	Improving operational efficiency, even on a smaller scale, still provides benefits in terms of cost reduction and increased productivity.

This table summarizes the findings on adopting technological innovations in the food and beverage industry. The most common innovation adopted by 40% of companies is production automation, contributing to increased efficiency and reduced operational costs. Supply chain digitalization, adopted by 35% of companies, allows for improved supply chain coordination and reduced distribution times. 25% of companies have started using environmentally friendly raw materials, which supports sustainability and improves the company's reputation among environmentally conscious consumers. Large companies adopt more than one technology simultaneously, supported by more significant financial resources, thus strengthening their competitiveness and expanding market share. Meanwhile, small and medium-sized companies focus more on adopting one type of technology, usually in the form of automation, which still positively impacts productivity, albeit on a smaller scale. This table details how technological innovations are implemented and their impact on the sustainability and competitiveness of companies in the food and beverage industry.

3.2. The Impact of Technological Innovation on Sustainability

Based on the linear regression analysis results, there is a significant relationship between the implementation of technological innovation and corporate sustainability in the food and beverage industry sector. Companies that adopt automation and environmentally friendly technologies show an increase in operational efficiency while contributing to reducing environmental impacts. One of the most prominent impacts is a decrease in carbon emissions, with companies using these technologies reporting a reduction in emissions of between 15% and 20% in the past two years. This reduction in emissions is evident in companies that have automated their production processes and adopted renewable energy technologies. In addition to reducing emissions, more than 60% of companies surveyed reported that implementing technological innovation has significantly reduced energy consumption, especially in the production and distribution phases. Automation technology allows for increased energy efficiency through real-time control and optimization of production processes. As a result, there is a decrease in the company's operational costs by an average of 12% per year. This technology also helps companies increase productivity while reducing reliance on manual labour, which often causes inefficiencies. The digitalization of the supply chain plays a vital role in optimizing the use of resources, including raw materials and energy. With an integrated digital system, companies can monitor resource consumption more accurately and efficiently. This also contributes to a reduction in production waste by up to 10%, thus improving operational sustainability and helping companies save significantly on production costs. Several companies involved in the study also revealed that environmentally friendly technologies, such as renewable raw materials and biodegradable packaging, are increasingly in demand, especially in international markets. Global consumers, increasingly concerned about their environmental impact, choose products from companies implementing these technologies. This provides a competitive advantage for companies, as they meet the demands of increasingly sustainability-conscious consumers and enhance the company's reputation as an environmentally responsible entity. This reputation has been shown to strengthen consumer loyalty, ultimately driving market growth for companies focusing on green technology innovation. Adopting technological innovations, especially those related to automation and environmentally friendly technologies, has a significant positive impact on the sustainability of companies in the food and beverage sector. Reduction in carbon emissions, energy efficiency and reduction in production waste are some of the main impacts of implementing these technologies, which help companies meet environmental regulatory standards and increase their competitiveness in an increasingly competitive market.

Table 2. Impact of Technological Innovation on Sustainability and Competitiveness

Technology Category	Innovation	Impact on Sustainability	Effects on Competitiveness
Production Automation		Carbon emissions reduction of 15-20% in the last two years; Energy efficiency and operational cost reduction of an average of 12% per year.	Improve operational efficiency and productivity; Reduce reliance on manual labor.
Supply Digitalization	Chain	Reduction of resource consumption and production waste by up to 10%; Optimization of supply chain management with operational cost savings.	Increase transparency and control in the supply chain; Optimize inventory management and distribution.
Eco-Friendly Technology (Renewable Materials and Biodegradable Packaging)	Raw and	Increased consumer loyalty through reputation as an environmentally friendly company; Ease of international market penetration due to sustainability.	Enhance reputation in the eyes of environmentally conscious global consumers; Strengthen competitive position in international markets.

This table summarizes the impact of technological innovation on sustainability and competitiveness in the food and beverage industry. Production automation has contributed to a 15-20% reduction in carbon emissions in the last two years and a 12% reduction in operational costs per year. Automation also increases

operational efficiency and productivity and reduces reliance on manual labour. Supply chain digitization helps reduce resource consumption and production waste by up to 10%, enables optimization of supply chain management, and increases operational control and transparency. This strengthens inventory and distribution management, ultimately increasing the company's competitiveness. Green technologies, such as using renewable raw materials and biodegradable packaging, increase consumer loyalty and the company's reputation as an environmentally friendly entity. These innovations also facilitate international market penetration, strengthen the company's competitive position in the global market, and increase the company's appeal among consumers who care about sustainability issues.

3.3. The Impact of Technological Innovation on Competitiveness

Based on the regression analysis results, technological innovation has been proven to significantly impact increasing the competitiveness of companies in the food and beverage industry sector. Companies that adopt advanced technologies such as automation and digitalization can achieve a 25% increase in production efficiency compared to companies that have not implemented similar technologies. This increase in efficiency is visible in various operational aspects, from production speed to resource management. More than 70% of companies reported that implementing innovative technology has helped accelerate their time-to-market for new products. Through supply chain digitalization, companies can monitor the delivery of raw materials and finished products in real-time, which reduces the risk of late delivery and minimizes potential losses due to distribution disruptions. This monitoring provides a significant competitive advantage, especially for companies facing highly competitive and rapidly changing market dynamics. In terms of production, companies that adopt automation report a reduction in production time per product unit of up to 20%. This reduction allows companies to substantially increase their production capacity, meaning they can meet greater market demand and respond to consumer demand more quickly. In addition, this increase in production volume is also accompanied by a reduction in production costs, which ultimately increases the company's profit margin. Technological innovation also plays a role in improving product quality. 55% of companies using new processing technologies reported improved product quality, particularly regarding product consistency and safety. This technology enables companies to ensure that every product they produce meets stringent quality standards, essential for maintaining consumer trust and compliance with industry regulations. In the marketing realm, technological innovation, particularly in the form of digitalizing marketing strategies, enables companies to expand their domestic and international market reach. Companies can target consumers more effectively and efficiently by utilizing digital platforms and data-driven marketing technologies. Around 45% of companies reported a 10-15% increase in sales after implementing new technologies in their production and marketing processes. This shows that in addition to improving operational efficiency, technological innovation can strengthen product appeal in the market and open up opportunities for expansion into the global market.

Table 3. Impact of Technological Innovation on Competitiveness in the Food and Beverage Industry Sector

Aspects of Technology Innovation	Impact on Competitiveness
Production Automation	Increased production efficiency by 25%; Reduced production time per unit by 20%; Increased production volume and decreased production costs.
Supply Chain Digitalization	Real-time monitoring of raw material and finished product shipments; Reduce delivery delays and risk of loss; Accelerate time-to-market for new products.
Processing Technology Innovation	Improvements in product quality were reported by 55% of companies, especially in product consistency and safety.
Digital Marketing Strategy	Expanding market reach through digital platforms; Increasing sales by 10-15%; Increasing global market share.

This table summarizes the impact of technological innovation on competitiveness in the food and beverage industry. Production automation has resulted in up to a 25% increase in production efficiency, with a 20% reduction in production time per unit. It has also increased production volumes and reduced overall operating costs. Digitizing the supply chain allows companies to monitor the delivery of raw materials and finished products in real-time, reducing delays and the risk of loss. It also accelerates the time-to-market of new products, giving companies the advantage of responding to market changes more quickly. Innovation in processing technology has improved product quality, with 55% of companies reporting improved product consistency and safety. This has helped companies maintain higher quality standards and increased market appeal. Digital marketing strategies have allowed companies to expand their market reach, mainly through digital platforms, contributing to a 10-15% increase in sales. In addition, companies have also seen an increase in global market share, strengthening their competitive position in a broader and more dynamic international market.

3.4. Research Model Analysis

The research model applied to evaluate the relationship between technological innovation, sustainability, and corporate competitiveness shows significant and relevant results in the context of the food and beverage industry sector. Through a linear regression approach, it was found that the variable of technological innovation consistently has a positive effect on both dependent variables, namely sustainability and corporate competitiveness. In the regression analysis, the regression coefficient for the relationship between technological innovation and corporate sustainability was recorded at 0.65, with a significance level of p less than 0.01. These results indicate that increasing adoption of sustainability-oriented technologies, such as using renewable energy, more efficient process automation, and applying environmentally friendly technologies, significantly contribute to achieving corporate sustainability. These technologies help companies reduce resource consumption, minimize waste, and reduce carbon emissions, achieving increasingly stringent sustainability standards. This sustainability impact is essential in the context of changing environmental regulations that continue to develop and changes in consumer preferences that are increasingly concerned with the sustainability aspects of products. The relationship between technological innovation and corporate competitiveness also shows significant results, with a regression coefficient of 0.72 and a significance level of p less than 0.01. These results suggest that companies that are proactive in adopting technological innovations, such as production automation, supply chain digitalization, and digital marketing strategies, have a more significant competitive advantage. These technologies improve operational efficiency and productivity and enable companies to respond to market changes more quickly and accurately, enhancing their competitiveness. In addition, innovations in processing and distribution technologies also enable companies to accelerate product time-to-market, expand market reach, and improve overall product quality, ultimately strengthening the company's position in both domestic and international markets. The results of this research model confirm that adopting technological innovation is a crucial factor in improving the sustainability and competitiveness of companies in the food and beverage sector. The higher the level of technology adoption, the greater the positive impacts generated, both in terms of sustainability and competitiveness. Therefore, companies that invest in innovative technologies will be able to not only meet the increasing demands for sustainability but also strengthen their position in the competitive market. These results provide valuable strategic insights for companies in formulating technology and innovation policies to achieve long-term growth and sustainable competitive advantage.

3.5. Differences Based on Company Size

The study results show significant differences in the adoption of technological innovation between large and small or medium-sized companies in the food and beverage sector. This difference is mainly influenced by the availability of financial and technical resources owned by companies of various sizes. Large companies adopt more complex and advanced technologies, while small and medium-sized companies are limited to more spartan technological innovations. Large companies with more extensive capital and resources can invest in advanced technologies such as robotics, artificial intelligence (AI), and high-speed automation in their production and distribution processes. Robotics and AI technologies provide significant advantages in increasing efficiency, reducing human error, and increasing production scale. For example, implementing robotics in production allows large companies to increase production speed and volume while reducing labour costs drastically. In addition, AI is used in various operational aspects, from data analysis to supply chain optimization, which allows large companies to be more flexible and responsive to market changes and increase their competitiveness. Small and medium-sized companies often need financial and technical skills constraints, which limit their ability to adopt more advanced technologies. Companies in this category can generally only implement simpler technologies, such as basic process automation or digital management systems, to improve efficiency at a more limited operational level. For example, automation in small and medium-sized companies is often limited to increasing production efficiency in specific lines or implementing digital systems for inventory and order management. Nevertheless, adopting these technologies still positively impacts the sustainability and competitiveness of small companies, albeit on a smaller scale than large companies. Large companies are also better able to withstand the high initial costs of adopting advanced technologies and the costs of maintaining and training staff. They also have easier access to external capital to fund technological innovation through loans or investments. On the other hand, small companies often face difficulties in accessing adequate funding sources to make technology investments, so they must seek more cost-effective and affordable solutions. Another significant difference is that large companies tend to achieve a faster return on investment (ROI) from technological innovation, as their more significant economies of scale allow them to leverage new technologies more efficiently. In many cases, large companies can recover the cost of technology investments relatively quickly, especially when the technology adopted has an immediate impact on productivity improvements and operational cost reductions.

3.6. Discussion

The study revealed that technological innovation significantly improves sustainability and competitiveness in the food and beverage industry. Applying technologies such as automation, supply chain digitization, and using environmentally friendly raw materials significantly contribute to operational

efficiency and reduce environmental impact. Automation in production, adopted by 40% of companies, has a significant impact on increasing productivity. By reducing reliance on manual labour and speeding up production processes, automation allows companies to reduce operational costs by up to 20%. It also allows companies to consistently produce at scale, strengthening their competitive position, especially in an increasingly competitive global market. Supply chain digitization, adopted by 35% of companies, allows for better integration in raw material management, distribution, and logistics. This technology allows companies to monitor distribution flows in real-time, which reduces distribution times by up to 15%, increases transparency, and optimizes stock management. This efficiency helps companies respond more quickly to changes in market demand, significantly increasing their competitiveness. Using environmentally friendly technologies also plays a significant role in creating long-term sustainability. Companies that adopt renewable energy and biodegradable packaging report a 20% reduction in carbon emissions in the past five years. This helps companies meet increasingly stringent environmental regulations and improves their image in the eyes of increasingly environmentally conscious consumers. The study confirms that technological innovation is vital for improving operational efficiency, lengthening competitiveness, and meeting sustainability demands. Policy support and access to advanced technologies are essential for small and medium-sized companies to drive broader technology adoption.

4. CONCLUSION

This study highlights the importance of technological innovation in driving sustainability and increasing competitiveness in the food and beverage industry. Companies can significantly improve operational efficiency, reduce costs, and minimize environmental impact by adopting advanced technologies such as production automation, supply chain digitalization, and using environmentally friendly raw materials. Automation, implemented by 40% of companies in the study, has been shown to increase productivity and reduce reliance on manual labour. As a result, companies can reduce operational costs by up to 20% and increase production consistency and scale, which are competitive advantages in the global market. Supply chain digitalization has significantly impacted transparency and coordination between suppliers and distributors. With digital systems, companies can monitor distribution flows in real time, reduce distribution times by up to 15%, and increase efficiency in inventory management. This efficiency supports increased competitiveness and allows companies to respond to changes in consumer demand more quickly and accurately. Environmentally friendly innovations, such as the use of renewable raw materials and biodegradable packaging, also significantly improve a company's reputation in the eyes of consumers who care about environmental issues. With carbon emissions decreasing by 20% in the past five years, companies are meeting increasingly stringent environmental regulations and strengthening their image as socially and ecologically responsible entities. The results of this study indicate that companies that are proactive in adopting technological innovation have a more significant advantage in long-term competitiveness and sustainability. However, policy support and access to advanced technologies are needed to accelerate wider technology adoption, especially for small and medium-sized companies. These results provide important implications for policymakers and industry players in formulating sustainable innovation strategies in the future.

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