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Understanding FEFO in the Perishable Food Supply Chain: A Multi-Stakeholder Perspective from Indonesia

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Abstract. This study aims to gain an in-depth understanding of the implementation of the First Expired, First Out (FEFO) principle within the perishable food supply chain in Indonesia through a qualitative approach involving various stakeholders, including farmers, distributors, retailers, and consumers. The research was conducted using semi-structured interviews and case studies of several companies that have adopted the FEFO principle in their operations. The findings indicate a significant gap in the understanding and implementation of FEFO among supply chain actors. Modern distributors and retailers demonstrate a higher level of knowledge and practice compared to farmers and traditional retailers, who tend to be less familiar with shelf-life-based inventory management systems. The main barriers to FEFO implementation include a lack of documentation, limited technical training, inadequate logistics infrastructure, and high costs associated with technology adoption. Nevertheless, this study also reveals strategic opportunities to expand the application of FEFO through ongoing training, incentives for business operators, and collaboration between the public and private sectors to strengthen infrastructure. These findings contribute significantly to the formulation of policies and strategies aimed at enhancing the efficiency and sustainability of the food supply chain in Indonesia. The study recommends a cross-sectoral approach and the development of technology-based systems as key steps toward more effective and competitive management of perishable food.

Keywords: FEFO, Food Supply Chain, Perishable Food, Logistics Efficiency, Stakeholders.

1. INTRODUCTION

The perishable food supply chain is a critical component of the global food system, particularly in countries like Indonesia, where a significant portion of the population relies on fresh produce and other perishable items [1]. However, the inefficiencies in this supply chain often lead to substantial food waste, which poses economic, environmental, and social challenges [2]. According to the Food and Agriculture Organization (FAO), approximately one-third of all food produced globally is wasted, with fruits and vegetables being among the most affected categories [3], [4]. In Indonesia, the situation is exacerbated by factors such as inadequate infrastructure, lack of proper storage facilities, and insufficient knowledge about food management practices [5]. This highlights the urgent need for effective strategies to minimize waste and enhance the efficiency of the perishable food supply chain [2], [6].

One of the most promising strategies for addressing these challenges is the implementation of the First Expired, First Out (FEFO) principle [7]. FEFO is a stock rotation method that prioritizes the sale and distribution of perishable items based on their expiration dates. By ensuring that older products are sold first, FEFO can significantly reduce the likelihood of spoilage and waste [8], [9]. However, the successful implementation of FEFO requires a comprehensive understanding of the existing supply chain dynamics, as well as the collaboration of various stakeholders, including farmers, distributors, retailers, and consumers [10]. This study aims to explore the potential of FEFO as a sustainable business model in the Indonesian context.

Despite its potential benefits, the adoption of FEFO in Indonesia faces several challenges. These include logistical inefficiencies, limited consumer awareness, and a lack of technological integration within the supply chain [11]. Many stakeholders may not fully understand the importance of adhering to FEFO practices, leading to inconsistent application and ultimately contributing to food waste [8]. Additionally, the existing infrastructure may not support the necessary conditions for effective implementation, such as temperature control and proper inventory management [12]. Therefore, it is essential to identify and analyze these challenges to develop effective solutions that can facilitate the successful implementation of FEFO [13].

This research will employ a qualitative methodology, including interviews with key stakeholders in the agriculture, distribution, and retail sectors, as well as case studies of companies that have successfully implemented FEFO [14]. By gathering insights from various perspectives, this study aims to provide a comprehensive understanding of the barriers and opportunities associated with FEFO in the Indonesian perishable food supply chain [15]. The findings will contribute to the existing body of knowledge on food waste reduction and sustainable business practices, offering practical recommendations for stakeholders.

Furthermore, the study will explore the role of technology in enhancing the implementation of FEFO. Information and communication technology (ICT) can play a crucial role in improving supply chain transparency, facilitating better inventory management, and enabling real-time tracking of perishable goods [16]. By leveraging technology, stakeholders can make more informed decisions, ultimately leading to reduced waste and increased efficiency [17]. This research will also examine the potential for collaboration among stakeholders, emphasizing the importance of a coordinated approach to implementing FEFO effectively. In conclusion, the implementation of FEFO in the perishable food supply chain presents a viable solution to the pressing issue of food waste in Indonesia. By developing sustainable business models that integrate FEFO principles, stakeholders can enhance supply chain efficiency, reduce waste, and contribute to a more sustainable food system. This study aims to provide valuable insights and recommendations for policymakers, industry players, and consumers, ultimately fostering a more resilient and sustainable perishable food supply chain in Indonesia.

2. LITERATURE REVIEW

The management of perishable food products has become a central issue in global supply chain research due to their short shelf life and susceptibility to spoilage. Previous studies emphasize that effective inventory management systems, such as First-In, First-Out (FIFO) and First-Expired, First-Out (FEFO), play a crucial role in reducing food waste and ensuring product safety [13]. Unlike FIFO, which prioritizes the order of product arrival, FEFO focuses on expiration dates, thereby providing a more accurate approach to handling perishable goods. This principle ensures that products with shorter shelf lives are distributed first, aligning with food safety regulations and consumer protection standards [14].

Research has shown that the implementation of FEFO requires strong coordination across supply chain actors. According to [8], collaboration among farmers, distributors, retailers, and consumers is essential to ensure traceability and timely distribution of perishable products. However, gaps in knowledge, resources, and technology among different stakeholders often hinder the effective adoption of FEFO. Smallholder farmers and traditional retailers, in particular, face significant challenges in adopting advanced inventory management systems due to limited access to training and infrastructure [7].

From a technological perspective, the adoption of digital tools such as barcoding, RFID, and inventory management software has been proven to enhance FEFO implementation. Studies in developed markets show that automation and real-time monitoring significantly reduce product loss and increase operational efficiency [18]. However, in developing countries, including Indonesia, technological adoption remains uneven. High costs, lack of digital literacy, and weak logistics systems have been identified as persistent barriers to widespread implementation.

Policy and regulatory frameworks also play a vital role in supporting FEFO practices. According to FAO (2019), effective food safety standards and government incentives are necessary to encourage businesses to comply with shelf-life-based distribution systems [19]. In the Indonesian context, although food safety regulations exist, their enforcement and monitoring remain inconsistent, particularly in traditional market settings. This regulatory gap exacerbates the disparity in FEFO adoption between modern and traditional supply chain actors, creating inefficiencies and food loss.

Finally, several studies emphasize the potential of multi-stakeholder collaboration in overcoming barriers to FEFO implementation. Partnerships between government, private sector, and civil society can facilitate capacity building, infrastructure development, and knowledge transfer [20]. For Indonesia, a country with a highly fragmented food supply chain, such collaborations are essential to bridge the gap between modern and traditional actors.

Strengthening FEFO practices not only contributes to reducing food waste but also enhances food security, consumer trust, and the overall competitiveness of the national food supply chain [21].

3. RESEARCH METHODOLOGY

This study employs a qualitative approach to explore the implementation of the First Expired, First Out (FEFO) principle within the perishable food supply chain in Indonesia. This method was chosen to gain an in-depth understanding of the experiences, perspectives, and challenges faced by various stakeholders in the industry. Data were collected through semi-structured interviews with key stakeholders, including farmers, distributors, retailers, and consumers. These interviews were designed to elicit their views on the application of FEFO, as well as the barriers and opportunities present in the local context.

In addition to interviews, the research also involved case studies of several companies that have successfully implemented FEFO in their operations [14]. Through a detailed analysis of best practices and strategies employed by these companies, the study aims to identify key factors contributing to the successful application of FEFO [13]. The data obtained from these case studies will provide additional context and enrich the understanding of how FEFO can be effectively integrated into the perishable food supply chain in Indonesia.

Once the data were collected, thematic analysis was conducted to identify patterns and themes emerging from the interviews and case studies. The results of this analysis will offer comprehensive insights into the challenges and opportunities encountered in the implementation of FEFO, along with practical recommendations for stakeholders [22]. Thus, this research is expected to make a significant contribution to the development of sustainable business models within the perishable food supply chain in Indonesia.

4. RESULTS

This study reveals several important findings related to the implementation of the First Expired, First Out (FEFO) principle within the perishable food supply chain in Indonesia. Based on the results of semi-structured interviews and case studies, several key themes emerged: understanding of the FEFO principle, challenges of implementation, strategies for application, and the impact of FEFO implementation on supply chain efficiency.

4.1 *Understanding of the FEFO Principle*

The majority of respondents have a basic understanding of the FEFO concept; however, the depth of understanding remains limited, particularly among farmers and traditional retailers. Distributors and larger companies tend to have more structured systems in place for implementing this principle.

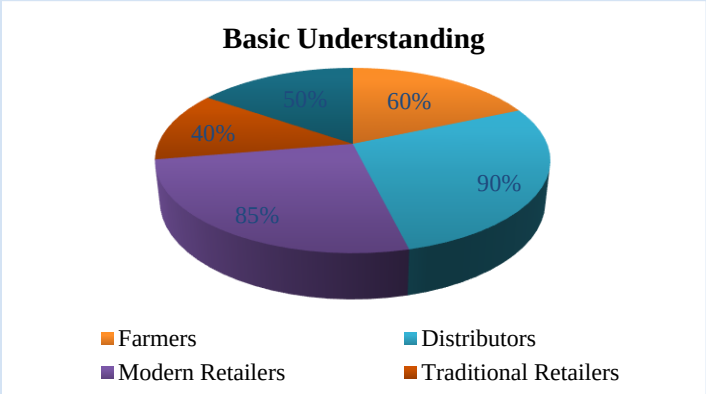

Figure 1. Basic Understanding of FEFO

Based on Figure 1 above, the level of basic understanding of the First Expired, First Out (FEFO) principle varies significantly among stakeholders in Indonesia's perishable food supply chain. Distributors exhibit the highest understanding (90%), followed by modern retailers (85%) and consumers (50%), while farmers and traditional retailers show lower levels at 60% and 40%, respectively. This disparity indicates that knowledge of date-based inventory management is unevenly distributed, aligning with [23], which suggests that downstream sectors are better

prepared to implement technology-based inventory management principles. In contrast, small-scale operators in the upstream sector often rely on manual practices and lack access to adequate training and information systems.

Furthermore [14], highlight that understanding logistics principles like FEFO is influenced by education, technological support, and exposure to modern supply chain practices. The knowledge gap between distributors and small-scale operators may hinder comprehensive FEFO implementation, emphasizing the need for stronger interventions from both government and private sectors, including training and affordable digital integration. For instance, the community-based logistics mentoring program proposed by [24] has effectively improved inventory management accuracy in West Java's horticultural cooperatives, demonstrating the importance of human resource readiness and cross-sector partnerships.

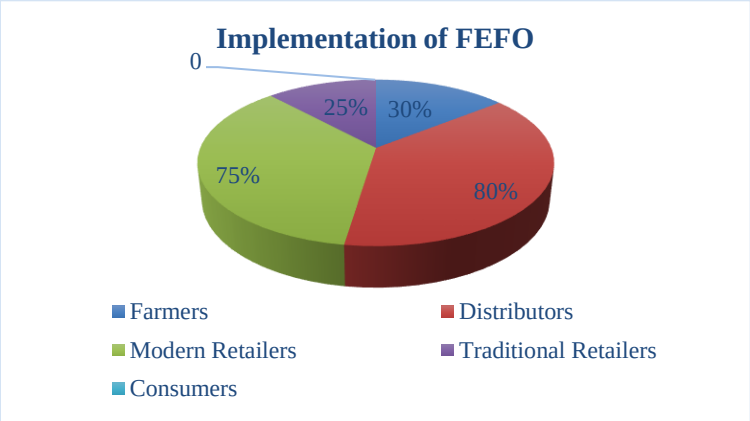

Figure 2. Implementation of FEFO

Based on Figure 2 above, the implementation of the First Expired, First Out (FEFO) principle varies significantly among stakeholders in the perishable food supply chain. Distributors and modern retailers show the highest implementation levels at 80% and 75%, respectively, largely due to their use of information technology in inventory management and logistics systems. This aligns with [22], who note that effective FEFO application relies on digital inventory systems like barcodes and ERP, commonly used by larger industry players. In contrast, farmers and traditional retailers have much lower implementation rates of 30% and 25%, reflecting their limited access to technology and lack of understanding of date-based inventory management. Further support this by indicating that small-scale operators often depend on visual methods or delivery sequences without considering expiration dates systematically [25]. Emphasizes that effective FEFO implementation at the upstream level requires intensive training, investment in record-keeping, and logistics integration [26]. These findings highlight the need for collaboration with small-scale operators and the provision of support systems, such as automatic date labeling and inventory management training, to enhance overall FEFO implementation.

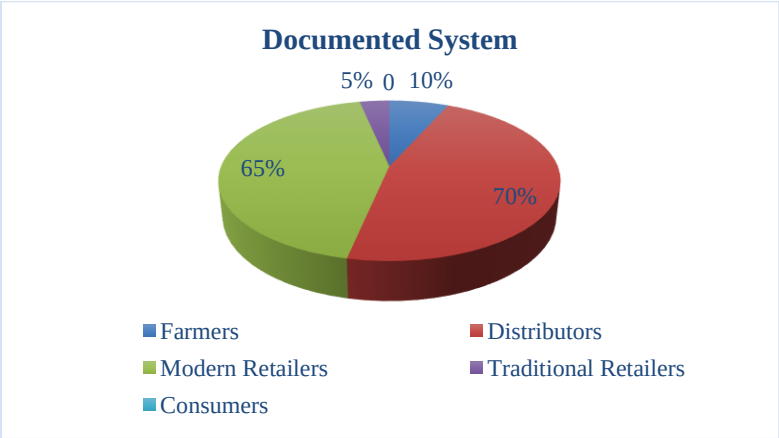

Figure 3. Documented System of FEFO

Based on Figure 3 above, the data shows the level of documentation of the FEFO system among stakeholders in the perishable food supply chain. Only distributors (70%) and modern retailers (65%) have significantly documented FEFO systems, while farmers (10%), traditional retailers (5%), and consumers (0%) lack such documentation. This highlights a substantial gap in structured inventory management systems. Distributors and modern retailers have integrated management information systems, such as ERP and barcode tracking, into their operations, as noted by [27], who emphasize that documentation is key for effective FEFO implementation in managing perishable products. In contrast, small-scale operators like farmers and traditional retailers often rely on manual methods or memory for managing product expiration, with over 80% lacking a documented expiration tracking system, according to [23]. This absence of documentation hinders their ability to evaluate and improve operations. Stresses that documentation is essential for operational efficiency and product traceability, especially in markets with strict quality standards [28]. Therefore, technical training and simple record-keeping systems are needed for small-scale operators, as demonstrated by a successful mobile app implementation in Yogyakarta that improved stock rotation accuracy by 40% [29].

4.2 *Challenges in Implementing FEFO*

The implementation of the First Expired, First Out (FEFO) principle faces several significant challenges that hinder its effectiveness in the perishable food supply chain. One of the primary issues is the lack of digital expiration tracking systems, particularly among farmers and small retailers, who often rely on manual methods that are prone to errors. This reliance on outdated practices can lead to increased food waste and inefficiencies in inventory management. Additionally, there is insufficient training and education regarding expiration-based inventory management, which prevents stakeholders from fully understanding the benefits and best practices associated with FEFO. Many small-scale operators are unaware of how to effectively manage their stock based on expiration dates, further exacerbating the problem. Furthermore, limited logistics infrastructure contributes to discrepancies between expiration dates and delivery sequences, making it difficult to ensure that products are sold in the correct order. Addressing these challenges is crucial for enhancing the overall efficiency of the supply chain and minimizing food waste, necessitating targeted interventions such as training programs and the development of accessible digital tools for better inventory management.

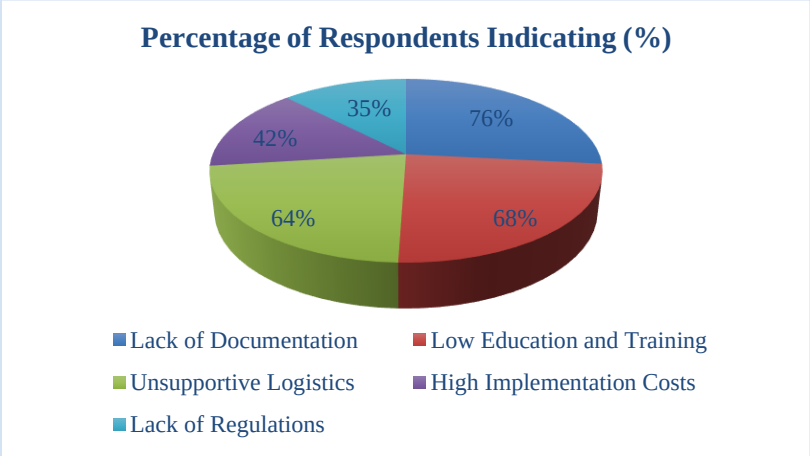

Figure 4. Key Challenges in the Implementation of FEFO

Figure 4 above reveals the various key challenges faced in the implementation of the First Expired, First Out (FEFO) principle within the perishable food supply chain in Indonesia. The most dominant challenge reported by respondents is the lack of documentation (76%), the high percentage aligns with findings from previous figures, which indicate that only a small fraction of stakeholders, such as distributors and modern retailers, possess documented FEFO systems. Wahyuni & Lestari (2021) highlight that documentation is a fundamental pillar in managing data-based inventory, and its absence complicates tracking, performance evaluation, and product auditing. Followed by low levels of education and training (68%), the lack of training poses a serious challenge, particularly among farmers and traditional traders. This is reinforced by [30], who state that only 1 in 10 small agribusiness operators have received formal training related to logistics or supply chain management. Ignorance of the FEFO concept leads to inconsistent and often incorrect implementation in the field. Unsupportive logistics (64%), Logistical issues, such as delivery delays, insufficient cold storage facilities, and poor road infrastructure, hinder optimal FEFO implementation.

According to [31], non-standardized logistics often result in perishable products being wasted before they can be marketed effectively.

Implementing FEFO requires a responsive and well-planned logistics system, which is often lacking in rural areas. High implementation costs (42%). The adoption of the FEFO system necessitates investment in labeling technology, inventory management systems, and human resource training, which are often unaffordable for small-scale operators. Emphasizes that small and medium enterprises (SMEs) in the food sector tend to view systems like FEFO as an additional cost burden rather than a long-term investment [22], [32]. The minimal regulations (35%), which mandate or encourage the implementation of time-based inventory management systems, also pose a barrier. The absence of national standards related to FEFO allows operators significant freedom in managing their products, often without considering food safety risks and distribution efficiency. Suggest the importance of government regulations that promote FEFO adoption, especially for high-risk food products [14], [33]. The data indicate that the successful implementation of FEFO requires not only technical understanding but also systemic support in the form of infrastructure, policies, education, and cross-sector collaboration. Therefore, strengthening documentation systems, enhancing human resource training, and improving logistics should be prioritized for intervention by the government, private sector, and academic stakeholders.

4.3 *Case Study of Companies Successfully Implementing FEFO*

To strengthen the findings of this research, a case study was conducted on five companies that have implemented the First Expired, First Out (FEFO) principle in managing their perishable food supply chains. These companies were selected based on variations in business scale, distribution sector, and the technological systems they employ. This study aims to assess the extent to which FEFO can reduce food waste and enhance inventory management efficiency across different types of companies. Below is a summary of the data from the five companies:

Table 1. Impact of FEFO Implementation in Company Case Studies

Company	Waste Level Before FEFO (%)	Waste Reduction (%)	Waste After FEFO (%)	Average Storage Time (Days)	Systems Used
PT Fresh Harvest	54%	35%	19%	3.2	ERP + Barcode System
PT Agro Sehat	47%	28%	19%	4.0	Independent Digital System
PT Sayur Organik Nusantara	38%	22%	16%	3.5	Mobile Inventory App + Manual Check
PT Tropis Segar Indonesia	50%	30%	20%	2.8	Cloud-Based Warehouse System
PT Prima Daging Lestari	42%	26%	16%	3.9	RFID + IoT Temperature Monitoring

As shown in Table 1, the significant impact of implementing the First Expired, First Out (FEFO) principle across five companies in the perishable food supply chain. PT FreshHarvest achieved the highest waste reduction of 35%, decreasing its waste level from 54% to 19%, largely due to its integrated ERP system and barcode tracking, which enable precise monitoring of product shelf life. Similarly, PT AgroSehat reported a 28% reduction in waste, maintaining a waste level of 19% after adopting a simpler, independent digital system that effectively supports stock rotation. The average storage times varied among the companies, with PT Tropis Segar Indonesia having the shortest average at 2.8 days, which likely contributes to its lower waste levels. In contrast, PT FreshHarvest, with an average storage time of 3.2 days, still managed to achieve significant waste reduction, indicating that effective management systems can mitigate risks associated with longer storage times. The variety of technological systems employed, ranging from mobile inventory apps to advanced RFID and IoT monitoring, reflects the adaptability of FEFO implementation across different operational contexts. Overall, these findings underscore that the successful adoption of FEFO can lead to substantial reductions in food waste, highlighting the importance of tailored technological solutions and ongoing training for stakeholders in the supply chain to enhance efficiency and sustainability in the perishable food sector.

5. DISCUSSION

This study highlights clear disparities in the understanding and application of the First Expired, First Out (FEFO) principle among actors in Indonesia's perishable food supply chain. Distributors and modern retailers show higher awareness and adoption due to the use of digital systems such as ERP, barcoding, and automated labeling, while farmers and traditional retailers remain dependent on manual methods with limited knowledge. These findings are consistent with [34], who underline the role of education and exposure to modern logistics, and [35], [36], [37], [38], who emphasize the importance of digital inventory systems. Similarly [23], argue that proper documentation ensures traceability, while found that reliance on memory reduces inventory accuracy [39]. Together, these studies confirm that technological integration and structured systems are central to effective FEFO implementation.

At the same time, collaborative approaches and accessible technology are necessary to overcome adoption barriers, especially for small-scale operators. Initiatives such as logistics mentoring programs [40] and mobile-based inventory applications [32], [41], [42] have shown positive impacts in improving stock rotation and reducing waste. These findings align with [43], who stresses the role of training and record-keeping, and [44], [45], who note that adequate logistics infrastructure is vital to reducing spoilage. Collectively, these seven studies reinforce the idea that FEFO adoption requires not only technical systems but also multi-stakeholder collaboration, capacity building, and government support to create a more efficient and sustainable perishable food supply chain in Indonesia.

The challenges identified in this study reaffirm the complex nature of implementing FEFO in Indonesia's perishable food supply chain. The most pressing issue is the lack of documentation systems, which hampers the ability of small-scale operators to track product shelf life and evaluate inventory performance. This finding supports [46], [47], [48], who argue that documentation serves as the backbone of data-driven inventory management, enabling traceability and compliance with quality standards. The reliance on manual practices among farmers and traditional retailers, as also observed by [49], [50], leads to inefficiencies and increases the likelihood of food waste, highlighting the urgent need for simple, affordable, and accessible digital solutions tailored for small operators.

In addition to documentation, insufficient training and weak logistics infrastructure represent major barriers that hinder FEFO adoption. The lack of formal education in logistics, noted by [51], explains why many small agribusinesses remain unfamiliar with expiration-based stock management, resulting in inconsistent application of FEFO in practice. Similarly, poor logistics infrastructure, such as limited cold storage and inadequate transport facilities, reflects the observations of [31], who emphasize that non-standardized logistics systems accelerate product spoilage and undermine supply chain reliability. These challenges demonstrate that without systemic improvements in both human resource capacity and logistics infrastructure, FEFO cannot be effectively implemented across all levels of the supply chain.

Finally, financial constraints and weak regulatory frameworks further complicate FEFO adoption. High implementation costs, particularly for SMEs, often deter investment in technologies like labeling systems and ERP software, confirming the argument that small businesses tend to perceive FEFO as a cost burden rather than an efficiency-enhancing investment [43]. Moreover, the absence of national standards or mandatory regulations on expiration-based inventory management, as highlighted by [22], gives operators excessive freedom in managing perishable products, frequently at the expense of food safety and efficiency. Therefore, successful FEFO implementation requires a holistic approach that integrates affordable technology, targeted training, supportive infrastructure, and strong government policies. Cross-sector collaboration between government, private industry, and academia becomes essential to build a sustainable and efficient perishable food supply chain.

The case studies confirm that the adoption of FEFO, supported by digital technologies, can significantly reduce food waste and improve inventory management efficiency. Companies such as PT Fresh Harvest and PT Agro Sehat achieved reductions of 35% and 28% respectively, demonstrating that both advanced ERP systems and simpler independent digital platforms can effectively support FEFO practices. These findings are consistent with [19], who emphasize that real-time monitoring technologies such as barcodes and digital platforms enhance traceability and accuracy in managing perishable products. Moreover, the shorter average storage time observed in PT Tropis Segar Indonesia (2.8 days) highlights the importance of synchronized logistics and rapid product turnover, echoing the insights of that efficient logistics infrastructure directly contributes to minimizing spoilage [18].

In addition, the variety of technological approaches used—ranging from mobile inventory applications to RFID and IoT-based monitoring—demonstrates the adaptability of FEFO across different business scales. This aligns with [14], who notes that the effectiveness of FEFO depends not only on the principle itself but also on the integration of appropriate technology and training for operators. The improvements observed across these companies reinforce the argument that structured documentation and digital support systems are fundamental to achieving sustainable inventory practices [13]. Thus, these case studies illustrate that FEFO can be successfully implemented in both large-scale and smaller enterprises, provided that investments are made in suitable technologies, human resource

development, and continuous monitoring to ensure long-term efficiency and competitiveness in the perishable food supply chain.

5.1 Opportunities and Recommendations

The findings indicate that the implementation of the First Expired, First Out (FEFO) principle holds significant potential for enhancing the efficiency and safety of the perishable food supply chain in Indonesia. FEFO not only aids in reducing food waste caused by expired products but also enhances consumer trust in product quality. However, to expand the national adoption of FEFO, a systematic and multi-sectoral approach is required. Several recommendations based on these findings are proposed:

a. Training and Technical Assistance for Small Business Operators

A significant number of farmers and traditional traders exhibit low levels of understanding and implementation of FEFO, as evidenced by previous data (with understanding at only 60% and 40%, and implementation at merely 30% and 25%). This underscores the need for practical training programs that not only explain the FEFO concept but also provide real-world application simulations. Research by [14], [15]indicates that enhancing human resource capacity is crucial for the adoption of food inventory management technologies, particularly for SMEs and the informal sector. Therefore, training programs should be coupled with ongoing mentorship to facilitate gradual behavioral change.

b. Incentives for Distributors and Retailers Adopting Digital Record-Keeping System

The adoption of digital expiration tracking technology remains limited to modern distributors and retailers (70% and 65%, respectively). The government could offer incentives such as tax reductions, software subsidies, or access to low-interest loans for businesses implementing these systems. According to [16], [17]Fiscal support has proven effective in accelerating technology adoption in the food supply chain across several Southeast Asian countries. Additionally, the use of mobile applications for shelf-life tracking could serve as a practical and affordable solution for small and medium-sized retailers.

c. Public-Private Collaboration for Strengthening Logistics Infrastructure

Logistics presents a significant challenge, with 64% of respondents indicating that existing infrastructure does not effectively support FEFO implementation. This includes the need for cold storage facilities, scheduled distribution systems, and automated labeling. Collaboration among local governments, business associations, and logistics providers should focus on developing standardized "fresh food logistics centers" in key producing regions for perishable commodities. A study by also emphasizes that government intervention in developing cold chain systems and digital traceability is a key lever for enhancing efficiency in the food supply chain [18], [20].

6. CONCLUSION

Based on the findings of this study, it can be concluded that the implementation of the First Expired, First Out (FEFO) principle within the perishable food supply chain in Indonesia still faces significant challenges, particularly in the upstream sector and among small-scale operators. While modern distributors and retailers demonstrate a relatively high level of understanding and implementation of FEFO, farmers and traditional retailers lag in terms of knowledge, application, and documentation of systems. These findings indicate a disparity in access to information, training, and technology that support shelf-life-based inventory management systems. The primary barriers to FEFO implementation include a lack of documentation, low levels of education and training, inadequate logistics, high implementation costs, and minimal regulations that promote these practices. Nevertheless, there is substantial potential to encourage broader adoption of FEFO through targeted technical training programs for small business operators, incentives for distributors and retailers who adopt digital record-keeping systems, and strengthened collaboration between the public and private sectors in developing logistics infrastructure. If these challenges can be addressed systematically and progressively, the implementation of FEFO has the potential to significantly enhance logistics efficiency, reduce food waste, and ensure the quality and safety of food products available to the public. Therefore, the successful implementation of FEFO requires a cross-sectoral approach and comprehensive policy support to create a more sustainable and competitive food supply chain in the future.

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