Optimizing Fruit Storage, Sorting, and Distribution in Packing Center to Minimize Waste During the Covid-19 Crisis

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Abstract

Effective storage sorting, and distribution of fruits will reduce the very high postharvest losses and waste. Consider the COVID-19 case in which supply chains across borders had been disturbed as several products spoiled. This therefore, proposes various ways through which fruit packing plants can advance further in enhancing sustainability and operation efficiency. A combined quantitative survey research and qualitative interview mixed-method design was conducted as research design for this study. A total of six orchards and six packing plants were targeted; 12 from the total 24 populations, respectively. Statistical tools include, in this case, descriptive statistics and content analysis. Key outcomes of improvement will be at storage, sorting, and distribution stages. The key improvements on fruits storage involve stacking fruits in assigned zones, periodical re-supplying stock to keep in balance, inspecting the same before storing. Heat-sensitive fruits should be stored in storage with fast circulation to avoid deterioration. Sorting should have a specific space for fruit placement and be sorted continuously to clear the stocks. Fruits should be oriented properly and labels placed for easy identification to ensure smooth handling. Fresh fruits should be handled with care, packed in the truck, lying first with heavier fruits at the bottom, with temperature-controlled containers for proper sorting by grade and size to be distributed efficiently. All these good practices will raise productivity, lower wastage, and increase better inventory accuracy. Long-term benefits would be ensured when fruit packing plants revisit their operational manuals to update the procedures for employees

Keywords: Optimization, Storage, Sorting, Packing Center, Minimize waste, Covid-19 crisis

1. Introduction

Farmers, producers, consolidators, sorting houses, processing factories, wholesalers, stores, and consumers all have numerous interests involved in the fresh fruit and vegetable production and distribution (Schoorl & Holt, 1982). Every entity contributes differently to preserve supply chain safety and efficiency (Nosratabadi et al., 2020). Among these, fruit packing companies are a vital middleman that guarantees that produced goods satisfies agricultural quality criteria

before they go on the market (Berk, 2016). Commonly known as "Lhong," a packing house is a facility assigned to post-harvest handling of fresh fruits and vegetables including activities including receiving raw materials, sorting, packaging, and distribution (Ministry of Agriculture and Cooperatives, 2011; Committee of Commerce, Industry and Labor, National Legislative Assembly, 2016). Both domestic consumption and export depend on these facilities' basic ability to use appropriate sorting techniques to preserve product quality and safety (Puangpetch Nittayanon, 2018).

The COVID-19 epidemic seriously interrupted world supply systems, posing important difficulties for the fruit packaging sector (Marusak et al., 2021). In response, Thai fruit exports—including durian, longan, mangosteen, and coconut—were subject to strict inspection procedures enforced by regulatory organizations such the General Administration of Customs of the People's Republic of China (GACC). These checks sought to guarantee adherence to phytosanitary rules and avoid contamination of agricultural output. Working with plantation owners and packing facilities, the Department of Agriculture performed remote evaluations via VDO conferencing, therefore effectively satisfying all necessary evaluation criteria to remedy these issues (Thairath Online, 2021).

In-depth interviews with packing house operators exposed ongoing operational difficulties even with these legislative initiatives. Particularly during supply chain delays, important issues included inadequate crisis response strategies and lack of systematic best practices in fruit handling. Pandemic-induced logistical restrictions seriously interrupted fruit distribution to both local and international markets, resulting in significant losses for exporters and manufacturers (Chenarides et al., 2020). Many packing factories also lacked set procedures to guarantee the manufacturing of premium, safe fresh fruits and vegetables in line with sound agricultural techniques (Setthachotsombut et al, 2024; Puangpetch Nittayanon, 2018).

Particularly in crisis like the COVID-19 epidemic, improving the storage, sorting, and distribution methods in fruit packing plants is vital given these difficulties to minimize loss and lower rejected product (Trakoonsanti et al., 2025). Methodical modifications in three key operational areas help one to raise resilience of the fruit supply chain, reduce losses, and enhance efficiency. This study aims to find solutions to make these processes better so ensuring long-term profitability and sustainability in companies dealing in fruit packing.

1.1 Research Objective

1. To examine and improve the processes of fruit storage, sorting, and distribution in fruit packing center to minimize losses and waste, particularly in response to challenges posed by the COVID-19 crisis.

2. To evaluate the effectiveness of enhanced storage, sorting, and distribution methods in reducing post-harvest losses and waste, thereby improving operational efficiency and sustainability in fruit packing center.

2. Research conceptual Framework

The conceptual framework as shown in Fig.1 will explain in detail how the fruit packing centers will be able to improve their operational efficiency towards better storage, sorting, and distribution of reducing waste and bringing down the numbers of fruits and vegetables that have been getting wasted, particularly due to COVID-19. The three key enhancements to the processes would translate into increased levels of operational efficiency that would further

cause three major results: reduction of produced waste, minimal discarding of the wastes, and improved accuracy regarding fruit management.

Sorting is also crucial in product quality preservation whereby the fruits have to be classified as per size, grade, and condition to avoid fruits from going rotten pre-maturely. Therefore, the products can easily overpower it. Effective storage management ensures freshness because proper storage manages systematic fruit placement inside the storages and also has a proper handling of the produce that has specific temperature toleration to avoid destruction. It creates efficiency in addition due to effective distribution: the fruits are not bruised while loading, transportation is under optimum conditions, and they are then systematically arranged according to size and weight to prevent damage.

Improvement in the sorting, storage, and distribution mechanism at the fruit packing centers can ensure an overall efficiency that reduces the volume of waste and discarded fruits while increasing the accuracy of inventory and quality control. It will add to the economic benefits, thereby adding to the sustainability of resources by reducing their wastage. Therefore, revision of operational protocols by fruit packing centers and the embracing of updated methodology is highly pressed for in this paper to enable it to hold up to challenges at present times.

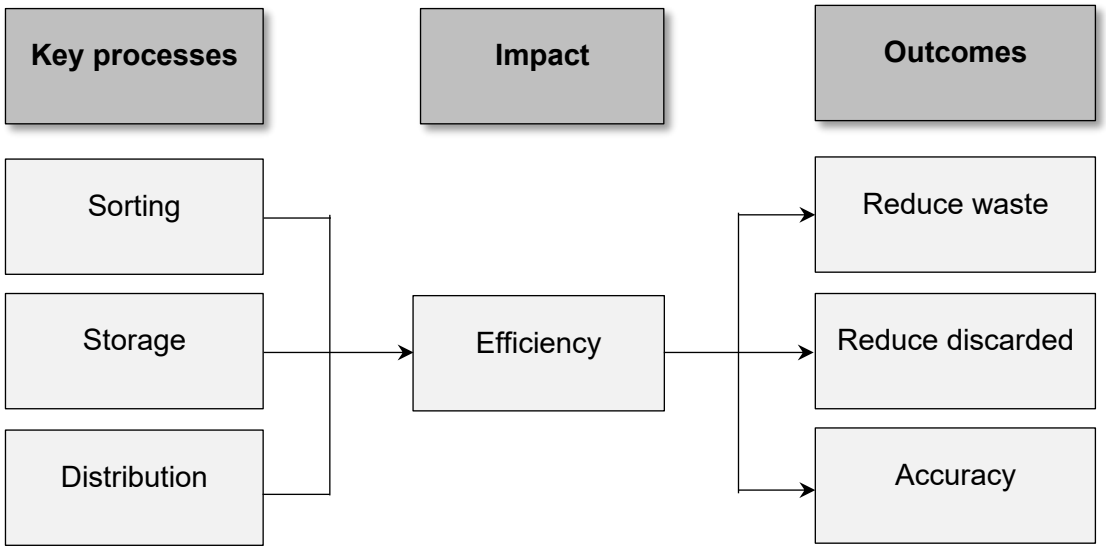

Figure 1. Conceptual Framework

3. Literature review

Organization of Fruit Distribution

Farmers typically sell their output to central markets, where prices are set depending on fruit size and market demand; so, the fruit distribution system entails several stakeholders (Schoorl & Holt, 1982). Seasonal changes affect the supply chain as some fruit kinds are accessible all year long while others are picked during particular times (Lu et al., 2024). Trucks are the main means of mobility used for fruit distribution as they help product to be moved from fields to different sales locations (Ge et al., 2014). Local vendors, market merchants, middlemen, and fruit packing companies (Lhong) are the major distribution routes; they are very important for exporting fruits to foreign markets. The effectiveness of this distribution system directly affects

the availability and cost of fruits in home and international markets (Oberoi & Dinesh, 2019; Thai Post, 2021).

Improving Storage, Sorting, and Distribution of Fruits

- Storage : Minizing losses and preserving fruit quality depend on effective storage management. A basic approach for minimizing spoiling is to balance the input and outflow of stored fruit thereby optimizing its amount. By using the First-In- First- Out (FIFO) concept, fruits are guaranteed not to stay in storage for too long, therefore compromising their shelf life. Fruit should preferably be handled and transported under a transshipment strategy within 24 hours to stop too rapid degradation (Buhion et al., 2024). Further guarantees the preservation of fruit quality by improving personnel handling practices to match industry standards—such as avoiding too forceful actions that can result in physical harm. Furthermore important in preventing contamination and maintaining freshness is the use of suitable storage containers free of chemical interaction with fruits (Yu et al., 2024).

- Sorting : Good sorting guarantees uniformity in fruit quality and reduces processing time. Modern sorting techniques dependent on weight, size, and appearance will enable faster, more precise grading and aid to simplify the categorization process. Maintaining acceptable standards in fruit delivery requires lowing sorting errors. Including artificial intelligence (AI) and automated sorting technologies might especially increase accuracy, efficiency, and consistency, so enhancing the whole performance of the supply chain (Attah et al., 2024).

- Distribution: Expanding distribution channels is especially important for easing logistical congestion in emergencies like the COVID-19 pandemic. Lhong facilities have historically largely supplied fruits to important local marketplaces and export hubs. But restrictions on foreign trade and transportation substantially hindered fruit distribution over the pandemic, resulting in a stockpile of unsold goods. Three various approaches have been proposed to address these challenges: (i) E-commerce systems By means of digital marketplaces, more flexible and direct transactions are made feasible to enable consumer-to-consumer (C-to--C) sales . This method reduces dependency on conventional distribution channels and helps to provide market accessibility (Takagi, 2020). (ii) Approaches of direct marketing and multi-level marketing (MLM) are: Direct linkages between manufacturers and end consumers—including corporate buyers—help to improve sales effectiveness. Businesses can be contacted for large purchases for either staff welfare initiatives or commercial needs (Ezekiel and Toba, 2020). (iii) Social Initiatives and Donation Programs Leveraging social networks to promote fruit sales for charitable purposes, such as donations to hospitals, low-income communities, and frontline workers, helps to avoid waste while supporting social welfare initiatives (Jung et al., 2022; Moryadee et al., 2025).

Best Methods for Fruit Packing Centers Through the COVID-19 Pandemic

Maintaining fair trade standards is essential to guarantee viable company operations during emergencies like the COVID-19 epidemic. Packaging companies should follow moral procurement guidelines by paying reasonable prices to farmers and avoiding exploitative pricing policies. Adopting internationally recognized accreditation criteria and ensuring compliance with food safety regulations will assist to increase consumer confidence and facilitate market development even further. Using these best practices will help the fruit sector to be sustainable over the long run.

• *Efficiency in Fruit Packing Operations*: The profitability and sustainability of fruit packaging operations depend much on the state of business performance. Multiple criteria allow one to evaluate efficiency in fruit packing centers: financial stability, product quality, market reach, and shareholder returns (Richard et al., 2009). Companies who purposefully reinvest in operational improvements—such as upgrading technology, implementing quality control procedures, and simplifying supply chain logistics—are more likely to remain resilient and constantly growing despite changes in the market (Fugate et al., 2010).

• *Loss Reduction Strategies*: Reducing fruit losses needs for a whole approach encompassing developments in sorting, storage, and transport. Improved operational procedures and standardized criteria let packaging firms to lower waste and inefficiencies. Reaching long-term sustainability goals and tracking development depend on the well defined waste reduction measurement criteria. By combining technology with best practices in logistics, sorting, and handling, one may help to reduce the overall thrown away produce (Bharti et al., 2024).

• *The Impact of the COVID-19 Crisis on the Fruit Industry:* The COVID-19 outbreak severely impacted global supply chains—including the fruit industry (Marusak et al., 2021). First reported in Wuhan, China, on January 3, 2020, the illness rapidly spread to create a global health crisis. The Chinese government responded with rigorous lockdown policies including travel bans and public transit network shutdown (Prachachat, 2020). These policies seriously interrupted trade routes, therefore restricting the flow of products and generating major supply chains congestion. One important fresh fruit supplier to China, Thailand, suffered directly from these limitations. The General Administration of Customs of the People's Republic of China (GACC) answered by requiring rigorous inspection processes for Thai fruit exports including durian, longan, mangosteen, and coconut. These tests aimed to control contamination and ensure phytosanitary compliance. Adopting digital technologies like VDO conferencing-based remote assessments to assist export permits, the Thai government and industry stakeholders therefore accepted following pandemic-related safety procedures (Thairath Online, 2021).

The COVID-19 epidemic underscored generally the necessity of increased flexibility and creativity in fruit delivery networks. Reducing future disruptions mostly depends on using technology, spreading out channels of distribution, and building strong logistical systems. These techniques used together will help fruit packing centers over time improve sustainability, reduce losses, and increase efficiency.

5. Research Design and Methodology

In the present study, a combined quantitative and qualitative research design was adopted to effectively provide a wide array of understandings pertinent to the improvement in the storage, sorting, and distribution of fruits within packing center. The quantitative design involves structured questionnaires for the purpose of data collection on a large sample basis efficiently, while qualitative designs use in-depth interviews in order to look further into the prevailing practices and challenges of fruit packing operations.

Population and Sample

The total population consists of 12 fruits orchards and 12 fruits packing centers, amounting to a total of 24 in all aspects (Thairath Online, 2021). Through purposive sampling, the sample size included 6 fruits orchards and 6 fruits packing houses, totaling to 12 respondents. This

helped ensure that the respondents selected had acquired enough experience and knowledge about storage, sorting, and distribution of fruits, therefore yielding relevant data.

Data Collection

It is the quantitative part-an online questionnaire forwarded to selected orchards and packing houses. This method would, therefore, be efficient for data collection from a number of places and yield a large volume within a very short period. The questionnaire focuses on operational practices, challenges, and the effectiveness of various strategies to reduce wastes. Semi-structured, in-depth interviews with key personnel from the selected orchards and packing houses were used for the qualitative component. These interviews explored experiences, opinions, and challenges of the participants concerning the processes of storage, sorting, and distribution. Participants were selected based on their expertise and direct involvement in fruit handling operations.

Research Instruments

The five members of this multidisciplinary committee included three academic experts and two industry professionals in the field of fruit supply chain management. Further, the research instrument has been tested for content validity and IOC index, and all items get an IOC score of 1.0, hence showing a strong content validity index. The interview guide was constructed in such a way that it would complement the questionnaire in explaining specific issues, such as operational improvements, strategies of waste management, and practical challenges faced during the COVID-19 crisis.

Data Analysis

Quantitative data analysis used descriptive statistics-frequency, percentage, mean, and standard deviation-to summarize and interpret the key trends of fruit storage, sorting, and distribution efficiency. Responses were audio-recorded and then transcribed to allow content analysis, focusing on the emergence of common themes, patterns, and insights from interview responses. Interview findings were cross-checked against quantitative results for consistency and to deepen the understanding of the research problem. It allowed the study, through a mixed-method approach, to embed numerical data in most of the in-depth qualitative insights, thus offering comprehensive investigations on fruit packing operations, waste reduction, and efficiency improvement.

6. Results

The results of this study were analyzed using statistical methods have summarized as shown in Table 1, providing a comprehensive understanding of the effectiveness of improving fruit storage, sorting, and distribution processes in reducing waste and discarded products. The analysis, based on responses from 120 participants, revealed significant improvements in operational efficiency across key processes.

Table 1. Data analysis from the results of this study

Items	Opinion level (n=120)			
	Mean	S.D.	Interpret	Rank
Key processes	**4.55**	**0.64**	**The most**	**-**
1. Sorting	**4.58**	**0.63**	**The most**	**1**

Items	Opinion level (n=120)			
	Mean	S.D.	Interpret	Rank
1.1 Separate the fruit zone and allocate the area proportionally, both determining the area to place fruit as appropriate. for convenience in efficient storage	4.92	0.75	The most	1
1.2 Sorting fruit to wait for replenishment all the time in clearing stock, bringing goods into storage and take it out to fill in the fillable part	4.80	0.69	The most	2
1.3 Arrangement of fruit, the direction of the fruit should be correct in order to clearly display the fruit information in case of labeling	4.89	0.66	The most	3
2. Storage	**4.51**	**0.63**	**The most**	**3**
2.1 Arrangement of fruits in an orderly designated area	4.75	0.68	The most	3
2.2 Fruits that are not suitable for storage in normal temperatures, cannot tolerate hot weather. Should be controlled in rapid circulation storage, should not be kept in stock	4.79	0.69	The most	2
2.3 Fruits should be inspected well before they are stored in the area	4.82	0.75	The most	1
3. Distribution	**4.56**	**0.65**	**The most**	**2**
3.1 Loading fruit into the car must be done with care, be careful not to damage and damage the fruit	4.73	0.72	The most	1
3.2 Placing and sorting fruits in temperature-controlled containers, taking into account the efficient use of space, and sorting according to the size of the heavy fruits placed on the bottom	4.70	0.68	The most	2
3.3 Distribution of fruits from many sources including grading, sizing, and graded fruit	4.68	0.65	The most	3
Outcomes	**4.58**	**0.61**	**The most**	**-**
1. Reduce waste	**4.61**	**0.59**	**The most**	**1**
1.1 Reduces wasted time from waiting for delivery of the product, due to the good storage of fruit making work faster	4.61	0.58	The most	3
1.2 Reduces storage time due to the improvement of the orderly fruit placement process	4.61	0.59	The most	3
1.3 Reduces search time for fruit Makes searching faster, because the space is organized by product group/size	4.64	0.58	The most	1

Items	Opinion level (n=120)			
	Mean	S.D.	Interpret	Rank
1.4 The number of damaged fruits has been reduced. Because there is care, inspecting the fruit completely, and accurately	4.62	0.57	The most	2
2. Reduce discarded	**4.58**	**0.63**	**The most**	**2**
2.1 Losses can be reduced, due to document checks, and continuous fruit sorting	4.57	0.64	The most	2
2.2 The number of expired fruits can be reduced, because the fruits are regularly inspected	4.52	0.68	The most	3
2.3 Can be discarded, because the fruit is maintained to maintain its original state	4.65	0.57	The most	1
3. Accuracy	**4.57**	**0.62**	**The most**	**3**
3.1 Good fruit picking results in the fruit being intact in the amount stored, and in the designated location	4.58	0.63	The most	1
3.2 Efficient fruit picking will ensure that the fruit in the order fulfills the customer's requirements, and is picked according to the condition of the fruit storage in the storage	4.56	0.60	The most	3
3.3 Efficient fruit dispensing, will allow customers to get the full fruit exactly as they want	4.57	0.60	The most	2

The study found that sorting was the most critical process in fruit handling, with a mean score of 4.58 (S.D = 0.63), emphasizing its crucial role in keeping fruit quality and reducing losses. Among the key features of sorting, separating fruit zones and allocating space proportionally received the highest rating, mean = 4.92, S.D. = 0.75, emphasizing the importance of systematic storage regarding operational efficiency. Also, restocking fruit inventory regularly got a mean of 4.80 and S.D. of 0.69, while arranging fruits well for clear labeling obtained a mean of 4.89 and S.D. of 0.66, indicating that organized storage is vital for tracking and ensuring proper inventory management. In terms of storage (mean = 4.51, S.D. = 0.63), the most crucial factor was fruit inspection before placement in storage (mean = 4.82, S.D. = 0.75), ensuring that only high-quality fruits are stored. Maintaining rapid circulation storage for heat-sensitive fruits (mean = 4.79, S.D. = 0.69) and placing fruits systematically in designated areas (mean = 4.75, S.D. = 0.68) were also key contributors to minimizing spoilage. In the interim, distribution was rated as the second most important process with a mean of 4.56 and S.D. of 0.65; careful handling that avoids fruit damage was emphasized. The highest rating in this category involved fruits being carefully loaded into transportation vehicles at 4.73 (S.D. = 0.72), followed by the strategic placement of fruits in temperature-controlled containers at 4.70 (S.D. = 0.68) to attain maximum preservation during the entire transportation.

Besides these directly process improvement and better fruit management related factors, three very important outcomes reported from reduced fruit handling delay were waste reduction, fewer discarded items, and accurate results. Top item in waste reduction-4.61, S.D. = 0.59-actually came with swift fruit collection as mean = 4.64, S.D. = 0.58, hence greatly reducing the fruit handling delays themselves as well. The reduction of damaged fruits through

proper inspection and proper handling significantly contributed to lowering losses (mean = 4.62, S.D. = 0.57). The second highest ranked strategy was in maintaining fruit quality to preserve its freshness in the original state (mean = 4.65, S.D. = 0.57), with continuous inspection, not allowing it to decay (mean = 4.52, S.D. = 0.68), being the closest, in reducing discarded fruits (mean = 4.58, S.D. = 0.63). Lastly, accuracy in fruit handling (mean = 4.57, S.D. = 0.62) was improved through systematic processes, with ensuring fruit integrity and proper placement (mean = 4.58, S.D. = 0.63) being the highest-rated factor. Furthermore, meeting customer requirements through precise order fulfillment (mean = 4.56, S.D. = 0.60) reinforced the importance of efficient sorting and storage in maintaining high-quality supply chain operations.

7. Discussion and Conclusions

The results of this study reiterate the very important role that efficient handling practices-sorting, storage, and distribution-play in waste reduction, efficiency of the supply chain, and improvement in general operational accuracy. The quantitative results showed that systematic sorting, structured storage, and careful distribution greatly contribute to waste reduction and accuracy, and this was further supported qualitatively by industry insights from interviews during the COVID-19 crisis. These findings confirm earlier research works, such as those by Peeraphan Bhumidee et al. (2020), Suchin Thongsoi (2021), and Worawut Kanghan et al. (2020), all of which stated that structured logistics would contribute to higher productivity with less loss.

Among the key processes, sorting emerged as the most influential factor in waste reduction, underscoring the necessity of well-organized inventory management. In light of these processes, this present study identifies space allocation for zone separation to prevent overstocking and wastages due to inefficient storage retrieval while continuous clearing stock replenishes overstock (Sudiarta et al., 2020). Overstock results in unnecessary wastages, since its systematic cycling enables the handling process to handle product traceability as well, most especially, arranging fruits clearly provides clear display labelings to identify them to clients. These findings are consistent with the previous studies indicating that organized storage significantly reduces product loss rates due to reduced risk of misplacement and damage (Mustafa et al., 2024; Shahbazi et al., 2025).

The results also highlighted the role of good storage management in maintaining fruit quality and reducing waste. The interview findings particularly pointed out the need for designated storage areas where fruits are systematically arranged and regularly inspected before being placed in storage. Special care should be taken with fruits that are sensitive to heat, which should be kept in fast-circulating areas rather than long-term stockpiles. These practices ensure that perishable products remain in optimal condition, reducing spoilage and improving inventory turnover. This supports prior research indicating that maintaining a structured storage environment enhances operational efficiency and extends the shelf life of fresh produce (Wilson et al., 2017).

Distribution was also considered integral to good fruit handling, especially because it maintained the quality of fruits even during transportation (Shewfelt et al., 2014). The study emphasizes how proper loading must prevent bruising and other forms of damage, apart from correct strategic placements in a refrigerated container for maximum space with the integrity of the product maintained. Another important practice emerged from the quantitative and

qualitative findings: sorting fruits by weight and size, placing heavier fruits at the bottom. In addition to this, efficient distribution from various sources, coupled with grading and sizing, makes sure that consumers receive quality goods with minimal losses along the entire value chain (Schoorl & Holt, 1982, Yadav et al., 2022).

The overall test results prove that an integrated fruit handling approach, including efficient sorting and structured storage with optimized distribution, results in massive reductions in waste, lower numbers of discarded products, and increased accuracy for supply chain operations. These findings are particularly useful to inspire fruitful reflections among fruit producers, packing plants, and supply chain managers, in light of the COVID-19 crisis. This might be further developed into an efficient and greener system by adopting structured logistics, systematic inventory management, continuous inspection protocols, and optimized transportation strategies. Future studies might be conducted regarding the implementation of technological advancements, such as automated sorting systems and AI-powered inventory management, which could significantly enhance precision and operational efficiency within the fruit supply chain.

8. Contributions and avenues for future research

These findings give weight to revising the standard operational procedures in fruit packing houses, or Lhongs, to further improve the efficiency in sorting, storage, and distribution. Updates on standard operating procedures with consideration of current challenges and best practices in the industry can prevent colossal wastes and boost productivity. Fruits have to be sharply differentiated while sorting, with storage space allocation according to needs and stock rotation systemically worked out for good space utilization. Similarly, good labeling and storing of fruits shall ensure better inventories, lesser handling errors, and traceability. Distribution- The loading needs to be carried out with much care to prevent bruising or mechanical damage.

Place fruits systematically and symmetrically in the temperature-controlled container to maximize the utilization of space and maintain quality. Expanding channels of distribution and including downgraded or lower-grade fruits tend to minimize wastage whilst maximizing economic value. Storage areas should be provided for proper organization, and the fruits that are sensitive to high temperatures should be prioritized to ensure rapid movement to prevent spoilage and sustain quality standards. Future research should be carried out to learn how to adapt to new technologies, especially AI and automation, in the sorting, storage, and distribution of fruits. Regarding the possible application of AI-based solutions-automatic sorting, real-time inventory, and predictive logistics-these might increase efficiency and minimize loss while reducing time delays at an operational level. Other perspectives can also be directed to smart packaging and IoT monitoring systems, which offer plenty of opportunities in their optimal handling for fruit supply chain operations.

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