

Research Article

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The supply chain and its development concept of fresh mulberry fruit in Thailand: Observations in Nan Province, the largest production area

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Abstract: Nan province, the biggest cultivation area of fresh mulberry fruit in Thailand is located in four districts: Chaloe Phra Kiat, Bor Klua, Tha Wang Pha, and Wiang Sa. The production yield of mulberry is about 848.6 kg/acre/year; however, it is mostly sold as frozen product. The Queen Sirikit Department of Sericulture intends to develop a new marketing channel for fresh mulberry fruit. The present study was to explore the current situation of mulberry fruit supply chain management in Nan province and to propose a new supply chain model for fresh mulberry. To gather information about supply chain management, the supply chain operation reference (SCOR) model was utilized to investigate four members of the mulberry supply chains, including growers, primary middlemen, secondary middlemen, and customers. The SCOR model possibly identifies critical points in the current supply chain and five obstacles in the distribution of fresh mulberries that are improperly handled, affecting market channels and product quality due to a

lack of suitable knowledge and technology for postharvest handling. Active packaging technology of fresh mulberries from a previous study was introduced to design a new supply chain model, and it was found that this technology could extend the product's shelf life and preserve its freshness. Although the cost of the active packaging technology leads to a much higher cost on the newly developed supply chain compared to that of the traditional supply chain, the developed model could enhance new market channels, including selling prices, and provide growers with more benefits than the traditional supply chain.

Keywords: mulberry fruit, supply chain, obstacle, developed model

1 Introduction

Mulberry (*Morus alba* L.) is widely spread in several temperate regions such as the United States, Europe, and Asia. Historical records of mulberry refer to producing and selling mulberry for silk businesses, such as silk cultivation and production, in Asian countries and trade routes along the silk route in China [1]. According to world export statistics from 2020 by the World Integrated Trade Solution (WITS), Thailand exported 2,225 and 23,236 kg of raw silk and woven fabrics, worth \$30.85k and \$3486.65k, respectively [2,3]. Apart from the silk businesses, several studies have reported that mulberry fruit has high nutritional and pharmacological value. Mulberry is becoming more popular among health-conscious consumers, leading to an increase in mulberry cultivation.

According to the Queen Sirikit Department of Sericulture of Thailand [4], growers of mulberry leafy production for the silk industry are a major cluster of mulberry cultivation. The mulberry leafy production consists of 74,182 growers and 21780.90 acres of cultivation area, while the mulberry fruit cultivation has 901 growers and 441.30 acres of cultivation area. The northern part of Thailand is the

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major cultivation area of mulberry fruit (539 growers and 269.20 acres), while Nan province has the highest cultivation area (182.26 acres, 41.28% of the total cultivation area of Thailand) and has the highest fruit production yield (848.60 kg/acre/year), followed by Chiang Mai and Phrae provinces. The majority of fresh mulberries are produced and sold as frozen mulberries to processing industries. There is an increasing demand for fresh mulberries with a significantly higher price in Thailand. Some growers then tried to sell them as fresh fruits, but fresh fruits had some limitations in terms of logistics such as easily prone to damage resulting in a short shelf life and rapid deterioration caused by mold growth. Mulberry fruits are subjected to a variety of postharvest techniques to extend their storage life, including dipping in chemical solutions [5–7], organic gaseous fumigation [8–11], and packaging [9,12–15]. Based on previous work, an active packaging developed can potentially extend fresh mulberry shelf life for 4 days or a total of 7 days on a display condition. The application of the developed active packaging can create a new supply chain of fresh mulberry that will have impact on price, cost, time, and post-harvesting practices.

Supply chain management has been applied or investigated in several fresh produce such as rice [5], palm oil [6,7], leafy vegetables [8–10], blueberries [11,12], and bananas [13] to improve supply chains' effectiveness. The management of fresh mulberries has never been documented, owing to the fruit's short shelf life due to the lack of postharvest technologies. The supply chain operation reference model (SCOR model) was used as a standard tool to study processes, activities, and performance indicators from upstream to downstream for describing information or performance as well as a reference for improving or developing supply chain structures or processes to increase the efficiency of supply chain management [14]. SCOR model consists of five processes including plan, source, make, delivery, and return. Applying the SCOR model to agricultural supply chains, several researchers [15,16] have defined planning as activities dealing with planning of agricultural production and food processing including logistic activities. Sourcing activities include the sourcing of agricultural inputs, fertilizers, and packing materials. Agricultural production and food processing are indicated as make activities, while delivery activities cover product distribution, order management, transportation, and storage. Return can be arranged by Reverse Logistics. Although key performance indicators in SCOR are reliability, responsiveness (order fulfillment cycle time), agility, cost, and asset management efficiency, only order fulfillment cycle time and cost were collected. The model can be used to assess

process performance and identify a critical point in each process that influences the success of a product [17]. In addition, risk assessment is essential to the agricultural supply chain because the network of stakeholders is complex and uncertain. The supply chain is often encountered with several kinds of risk such as climate change, currency volatility, and disease outbreaks. Their impact is detrimental to business operations, such as production chain disruptions, increasing in production cost, and decreasing in customer demand [18]. Risk matrix is a tool to measure the level of risk associated with the severity and likelihood of an incident. In this way, visualized risks can be classified according to their priorities so that businesses can properly prioritize, manage their requirements, and monitor them [19].

This research will reveal the current situation of mulberry supply chains in Nan province. A new supply chain will be developed and compared with the traditional chain in terms of handling practices, time, cost, risk, and profit in the supply chain.

2 Materials and methods

2.1 The study's scopes

The research was a combination of quantitative and qualitative studies and focused exclusively on surveying supply chain members based in Nan province, Thailand. The monitoring areas encompassed four of Nan province's highest mulberry producing districts: Chaloem Phra Kiat, Bor Klua, Tha Wang Pha, and Wiang Sa.

Landforms were used as a physical geography to classify groups of mulberry production areas according to highland areas and plateau areas. The highland areas, Chaloem Phra Kiat and Bor Klua districts, are located on the steep slopes of mountains and about 730–1,600 m above sea level. Chaloem Phra Kiat district covers three mulberry fruit cultivation areas that are Ban Huai-Kan village, Phu Pha-Yak, and Doi Khun Nan. The Royal Highland Agricultural Development Station, located in Bor Klua district, is collaborating with the Phu Fa development center as part of Her Royal Highness Princess Maha Chakri Sirinhorn's Royal Initiative Project, with the primary objective of assisting mulberry growers in producing and selling their products in order to earn a better living. The plateau areas are located in Tha Wang Pha and Wiang Sa districts, 46.6 and 60.6 km away from the center of Nan, respectively.

2.2 Sample size determination, questionnaire development, and data collection

The respondents of this study were separated into two main groups, mulberry growers and middlemen. Face-to-face interviews were used to obtain the data. Questionnaires were designed covering qualitative and quantitative data based on the SCOR model. Dichotomous and close-ended questions were used for measuring a general information and fruit handling for each role of supply chain members, but open-ended questions were required for additional opinions. The grower role of supply chains is required to provide general information, mulberry cultivation knowledge, the current situation of production, cultivation planning, production, and distribution processes. The middleman role is requested to provide general information, planning and fruit collecting information, purchasing, receiving, and distribution. The number of respondents were calculated according to Yamane's formula [20], with a 99% confidence level and an allowable error value of 1% as shown in Table 1. The data was collected between December 2016 and February 2017.

2.3 Risk assessment

A risk assessment was conducted based on the questionnaire developed. The data scored with regard to impact and likelihood of risks identified [21,22] were applied to define and rank degrees or levels of risks via the below formula.

$$\text{Degree of risk} = \text{Impact} \times \text{Likelihood}.$$

The scores of impact include 5 scores as follows: 1 is no or very low direct effect on process; 2 is low deterioration in process; 3 is moderate deterioration in process; 4 is high deterioration in process; 5 is the highest deterioration in process or almost process cannot be executed. While the scores of likelihood include as follows: 1 is probability of once in many years; 2 is probability of once in many months; 3 is probability of once in many weeks; 4 is probability of almost weekly occurrence and 5 is probability of almost daily occurrence.

Then, degrees of risk were divided into 4 groups. First, 1–4 scoring group represents a low risk and accepts the risks as the probability of the risk occurring is small and its impact is minor. Second, 5–9 scoring group represents a medium risk and the operator should monitor the risks periodically to take actions to reduce the chance of

the risk occurring. Third, 10–15 scoring group represents a high-risk level and a risk mitigation plan to eliminate or minimize the impact of risk events should be prepared including monitoring the risks. Finally, 16–25 scoring group represents the very high level of risks, the risk events must be monitored continuously, a risk mitigation plan including an adaptation plan should be conducted as the risk event is inevitable and it is better to adapt operations to fit in to the new circumstances as well as the New Normal situation that we have been facing since 2020. Moreover, the risk data were analyzed based on the average risk values of the growers and the middleman.

2.4 Data processing and analysis

The collected data were coded and processed via Microsoft Excel spreadsheets and SPSS software version 19.0 of MS-Windows. The outlier data was removed via box-plot analysis, and the cleaned data were interpreted with descriptive statistics.

3 Results and discussion

3.1 Overview of supply chain actors

About 95.34% of growers are from the “Hmong” hill tribe located in the highland area, while other growers are Thai who live in the plateau area. About 60% of the middlemen are government officers who are working with the Royal High Land Agricultural Development Station and Phu Fa development center. More details about respondents are shown in Table 1.

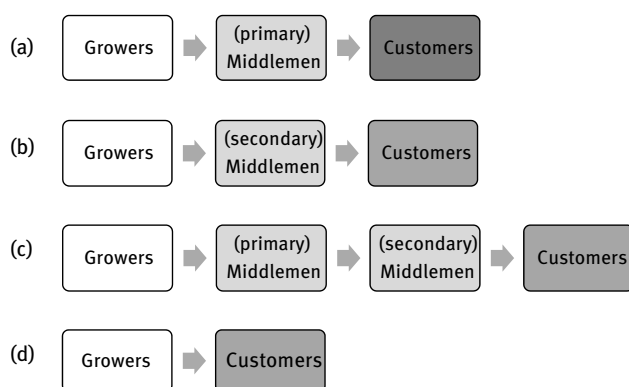
3.2 Mapping the mulberry fruit supply chain in Nan Province

According to the survey, there are four different supply chain structures for fresh mulberry fruit production (Figure 1). Contract growers are located in the highlands, whereas non-contract growers are positioned on the plateau. The contracted growers will sell their crops to the two government offices, which can be called “the primary middlemen.” The primary middlemen always purchase the products from the contracted growers in excess of 500 kg/time according to the contract, and they also provide

Table 1: General information of mulberry supply chain actors (count and % total)

Variable	Grower		Middlemen
	Highland area	Plateau area	
Respondent	161 (96.90%)	5 (3.10%)	5 (100.00%)
Gender			
Male	101 (62.74%)	2 (40.00%)	4 (80.00%)
Female	60 (37.26%)	3 (60.00%)	1 (20.00%)
Age			
Less than 21 years	2 (1.24%)	0 (0.00%)	1 (20.00%)
21–40 years	68 (42.23%)	0 (0.00%)	3 (60.00%)
41–60 years	76 (47.20%)	3 (60.00%)	1 (20.00%)
61 years and more	15 (9.33%)	2 (40.00%)	0 (0.00%)
Education level			
Not educated	68 (42.23%)	1 (20.00%)	0 (0.00%)
Primary school	36 (22.36%)	2 (40.00%)	0 (0.00%)
High school	50 (31.05%)	1 (20.00%)	1 (20.00%)
Diploma	4 (2.48%)	1 (20.00%)	1 (20.00%)
Undergraduate	3 (1.88%)	0 (0.00%)	3 (60.00%)
Occupation			
Farmer	160 (99.37%)	5 (100.00%)	0 (0.00%)
Officer	1 (0.63%)	0 (0.00%)	3 (60.00%)
Others	0 (0.00%)	0 (0.00%)	2 (40.00%)
Years of experience			
Less than 1	4 (2.48%)	0 (0.00%)	0 (0.00%)
1.1–2.0	17 (10.56%)	0 (0.00%)	0 (0.00%)
2.1–3.0	35 (21.74%)	1 (20.00%)	3 (60.00%)
3.1–4.0	23 (14.28%)	3 (60.00%)	1 (20.00%)
4.1–5.0	20 (12.42%)	0 (0.00%)	1 (20.00%)
More than 5	62 (38.51%)	1 (20.00%)	0 (0.00%)

saplings for the growers to plant as well. The secondary middlemen, or private middlemen, buy mulberry from non-contracted growers or the primary middlemen, and their purchasing volume is normally less than 500 kg/time due to their capability. Four distinct supply chains exist for mulberries as shown in Figure 1.

**Figure 1:** The structure of mulberry supply chains.

Structure A (Figure 1a): This structure is represented in highland cultivation areas. The growers act as the fresh mulberry fruit producers, and then the fruits are sold to the primary middlemen in big bulks. The two government offices, the primary middlemen, have as their main objective to improve the hill tribes for a better living by planting and selling mulberry fruits. They work as middlemen, including the distributor, processor, and wholesaler. They transform fresh fruits into frozen fruits and sell the products to industry customers. Two types of contracts are established that are the contract between the middlemen and the growers and the contract between the middlemen and the industry customers. A demand forecast will be conducted based on the contracts signed with the customers, while a purchasing plan will be organized based on the contracts signed with the growers in order to fulfill the customers' requirements. The middlemen Buy-to-Stock more than Buy-to-Order due to the fact that mulberry is a seasonal fruit, but the customer's demand ranges from January to December. Then, using a Buy-to-Stock policy, the primary middlemen can

synchronize the demand and supply of the mulberry fruit.

Structure B (Figure 1b): This supply chain structure is prevalent in mulberry fruit grown in highland and plateau cultivation areas. The secondary middlemen act as distributors, retailers, and occasionally processors. They buy the fresh fruit directly from growers (a surplus from the amount required by the primary middlemen) and then sell them to small-scale customers at local markets. However, the business of middlemen in this structure is more of Make-to-Order than Make-to-Stock. The secondary middlemen face significant risks since they are unable to forecast the volume and timing of consumer demand and lack collaboration with both customers and growers to plan and control the supply chain.

Structure C (Figure 1c): The role of secondary middlemen in the structure is limited to a frozen fruit dealer and distributor to a customer who needs a larger amount of frozen mulberry fruit, but less than the demand of structure A's customer. This supply chain can be beneficial to all the supply chain actors. However, the secondary middleman must satisfy customers by fulfilling the customers' demands in terms of quantity, quality, and time.

Structure D (Figure 1d): This structure is the simplest in terms of complexity and conditions, as its actors are growers and customers. This structure can be found in the plateau cultivation area. The role of the growers in this structure is comprehensive. They act as the producer, dealer, and distributor. Moreover, customers can easily access products from the geographical advantage of the production site located on the plateau area, and closed to public transportation routes. As a result, the logistics and transport cost of this supply chain are significantly lower than those of the others. However, the market channel is still limited to local markets with regard to marketing channels.

For customers' information, two groups of customers are defined including industrial and regular customers. The industrial customers are located far away from the production area such as Chiang Mai, Chiang Rai, and Bangkok. The product flows were defined as supply chain structures A, B, and C. Frozen mulberry fruits are the main needs of this customer group, but the customer demand of supply chain structure A is larger than that of structure B. The regular customer means the customer who often buy a small volume of products and their main purpose is mainly for consumption. The regular customers are scattered nearby the production area, and they can buy the product in local markets and week-end markets. There are only few fresh mulberries available on the

market due to postharvest management issues, leading to some consumers buying frozen mulberries instead. Frozen fruit can be kept longer and is easier to distribute under low temperature than fresh fruits but the appearance and taste are altered and the nutritional value is significantly reduced in variance with the storage time [23].

3.3 Analysis of the fresh mulberry fruit supply chain

The internal management of the growers and middlemen was separately interpreted based on the SCOR model.

3.3.1 The mulberry fruit production of growers

3.3.1.1 Plan

For the contracted growers, the official meeting of mulberry production planning is annually arranged by the Queen Sirikit Department of Sericulture in Nan province before the start of the growing season. Actors in the mulberry supply chain consist of growers, middlemen (both primary and secondary middlemen), and customers participating in the meeting. The main purpose of this meeting is a kind of supply chain planning as they discuss the predictable demand volumes from the customers and supply capability from the middlemen. After the meeting, volumes of purchasing orders from the primary middlemen will pass to the growers as a signed contract. This process can be called as sourcing plan and the information flow is the contract. The contracted growers will then prepare planting, culturing, harvesting schedules, including stocked production factors such as sapping, machinery, and others to make sure that they can fulfill the contracts. For non-contracted growers, they can run their farms from production to distribution on their own.

3.3.1.2 Source

All the contracted growers have passed the cultivation training provided by the two government offices. The cultivation area has been allocated by the primary middlemen, while the growers on the plateau have their own cultivation area. The primary middlemen supply the contracted highland and plateau growers with necessary cultivation facilities such as inputs, irrigation systems, saplings, and fertilizer. Furthermore, the growers can

plant the additional saplings by themselves. Most of the highland growers build an equipment storage hut (64.00%) and a product collecting hut (78.26%) in the orchard area, and their orchards are officially Good Agricultural Practices (GAP) certified. The plastic baskets provided by the primary middlemen are used as the package for collecting the harvested fruit of the highland growers, while the plateau growers also use the plastic baskets for collecting the harvested fruit, but they are not supported by any middlemen.

3.3.1.3 Make

Mulberry fruit production in the highlands and plateaus is very similar and can be divided into three steps: land preparation, planting, and harvesting, as shown in detail in Table 2.

Most of the growers do the land preparation steps. All the growers prepare pits before planting. Some of the highland growers often apply fertilizer and mix after pitting, while the plateau growers decide to add nothing into the pit. For the planting step, the 4 m × 4 m planting template is recommended for mulberry tree cultivation [24]. However, some plateau growers plant the trees in a 3 m × 3 m range because they need as many trees as possible in a limited cultivation area. After the planting process, about half of the growers apply various types of fertilizer to nourish mulberry trees such as manure, bio-compost, and chemical fertilizers. Moreover, we found only one plateau grower used a plant hormone to increase the production yield, while two highland growers used insecticide during cultivation. However, experts suggest that both herbicide and insecticide are unnecessary when the growers plant mulberry following the proper templates consisting of natural light, air ventilation, and easy to access, resulting in comfortable cultivation management [25].

Table 2: Details of mulberry growers' production processes in the highland and plateau

No.	Process	Description	Proportion (% of each grower group)	
			Highland growers	Plateau growers
1.	Land preparation	Doing own orchard preparation	98.75	60.00
		Pitting before plant	100.0	100.00
		Fertilizer adding into the pit before planting	17.39 (manure)	0.00
			5.59 (manure + bio-compost)	
			2.48 (manure + bio-compost + chemical fertilizer)	
2.	Planting	Plant the tree in 4 m × 4 m range	83.85	40.00
		Fertilizer adding into the pit after planting	28.57 (manure + chemical fertilizer)	40.00 (manure + bio-compost)
		Plant hormone using	0.00	20.00
		Herbicide using	0.00	0.00
		Insecticide using	1.24	0.00
		Trimming and bending the stem in the umbrella shape	97.51	100.00
		Excess-leaf removing	36.64	0.00
3.	Harvesting	Fruit stage harvesting	49.69 (fully ripe)	100.00 (75% ripe)
		Finger picking at fruit stem	53.41	60.00
		Hygienic rubber gloves wearing through harvesting	74.53	80.00
		Fruit collecting in the plastic basket	95.03	95.00
		A sheet of banana leaf underlying in the collecting basket	63.97	60.00
		The average weight of fruit load in each basket	2.40 ± 0.44 kg	3.20 ± 1.78 kg
		The average harvesting time	6.14 ± 1.59 h	5.80 ± 1.92 h
		Fruit basket was compiled on collection hut	61.49	60.00
4.	Delivery	More than 60 min placing in collection hut	98.13	80.00
		Less than 10 min for transport to purchasing point	94.41	100.00

The normal production season of mulberry fruit is set twice a year; in season begins in January and ends in April, and off-season begins in October and ends in December. Some orchards could produce the fruits all year using the plant hormone regulation and/or the stem-bending combined with stem trimming and excess-leaf removing techniques. Most of the growers trim and bend the stems into an umbrella shape. However, the excess-leaf removing technique was found in the highland growers. The main production from the highlands contains fully ripe fruit, but most plateau growers prefer to harvest 75% ripe fruit. More than half of the growers harvest fruits by finger picking at fruit stems rather than directly catching on the fruit's body that is still found among some growers. Most of the growers wear rubber gloves during harvesting, which possibly reduces the possibility of contamination from microbes on hand to fruits [26]. More than 95% of the growers collect the harvested fruit in a plastic basket that is underlaid with a sheet of banana leaf and the average weight of the fruit per basket is 2.40 ± 0.44 kg for highland growers and 3.20 ± 1.78 kg for plateau growers. The overlapping of soft and perishable fruits causes mechanical impact regulation called "compression injury," which has an impact on fruit texture damage and cell senescence, promoting short shelf-life [27]. Most of the growers start the harvesting process in the early morning around 5–6 a.m. and the average harvesting lead time is not significantly different between the groups of the growers, as the average harvest time is 6.14 and 5.80 h for the highland and plateau growers, respectively. After that, more than half of the highland growers collect the harvested fruits and store them in a collecting hut, but some of the growers amass all the harvested fruit in other places such as under a big shard tree, and on the ground in the orchard, while most of the plateau growers also store fruits in a collecting hut. Before the delivery process, all fruits in the orchard will be kept in a collecting hut under ambient temperature for more than 60 min by about 98.13% and 80.00% of the highland and plateau growers, consecutively.

3.3.1.4 Delivery

To deliver mulberries, most of the growers walk no more than 10 min to the purchasing point, as it is very near to their orchard. When the distance is too far to walk, motorcycles or pickup trucks are used. The highland growers carry 13.92 ± 10.08 fruit baskets/delivery round,

but the plateau growers carry 5.40 ± 4.22 fruit baskets/delivery round.

3.3.1.5 Return

After finishing the purchasing process, the contracted growers will receive the harvesting basket back, or they can get a new one from the primary middlemen if it is broken. On the other hand, the non-contracted growers will have to invest on their own.

3.3.2 Middlemen's mulberry fruit collection

3.3.2.1 Plan

As mentioned in Section 3.3.1.1, the primary middlemen arrange the annual meeting with their contracted growers, non-contracted growers, secondary middlemen, and customers to inform them about the requirements of mulberry in terms of quantity, quality, and time. Moreover, training courses on mulberry fruit cultivation for new growers will be provided by the primary middlemen. At the end of the meeting, both demand and supply for each month will be confirmed. A sourcing plan for mulberry will then be developed by the middlemen.

3.3.2.2 Source

The primary middlemen have their own purchasing location boundaries. Phu Pha-Yak and Khun Nan Royal Highland Agricultural Development Station purchase the products from the contracted growers located in Chaloem Phra Kiat district, while Phu Fa development center purchases the products from the contracted growers located in Bor Klua district. For the secondary middlemen, they can purchase from any farms. Both the primary and secondary middlemen prepare the polypropylene baskets, polyethylene (PE) plastic bags, carton boxes, digital balances, and deep freezers for using in the purchasing and processing processes. The primary middlemen receive funding from the government to acquire a temperature-controlled truck and freezing containers for storing and distributing the products, whereas the secondary middlemen incur a higher cost for vehicles to collect and distribute the products because they must invest their own funds (Figure 2).

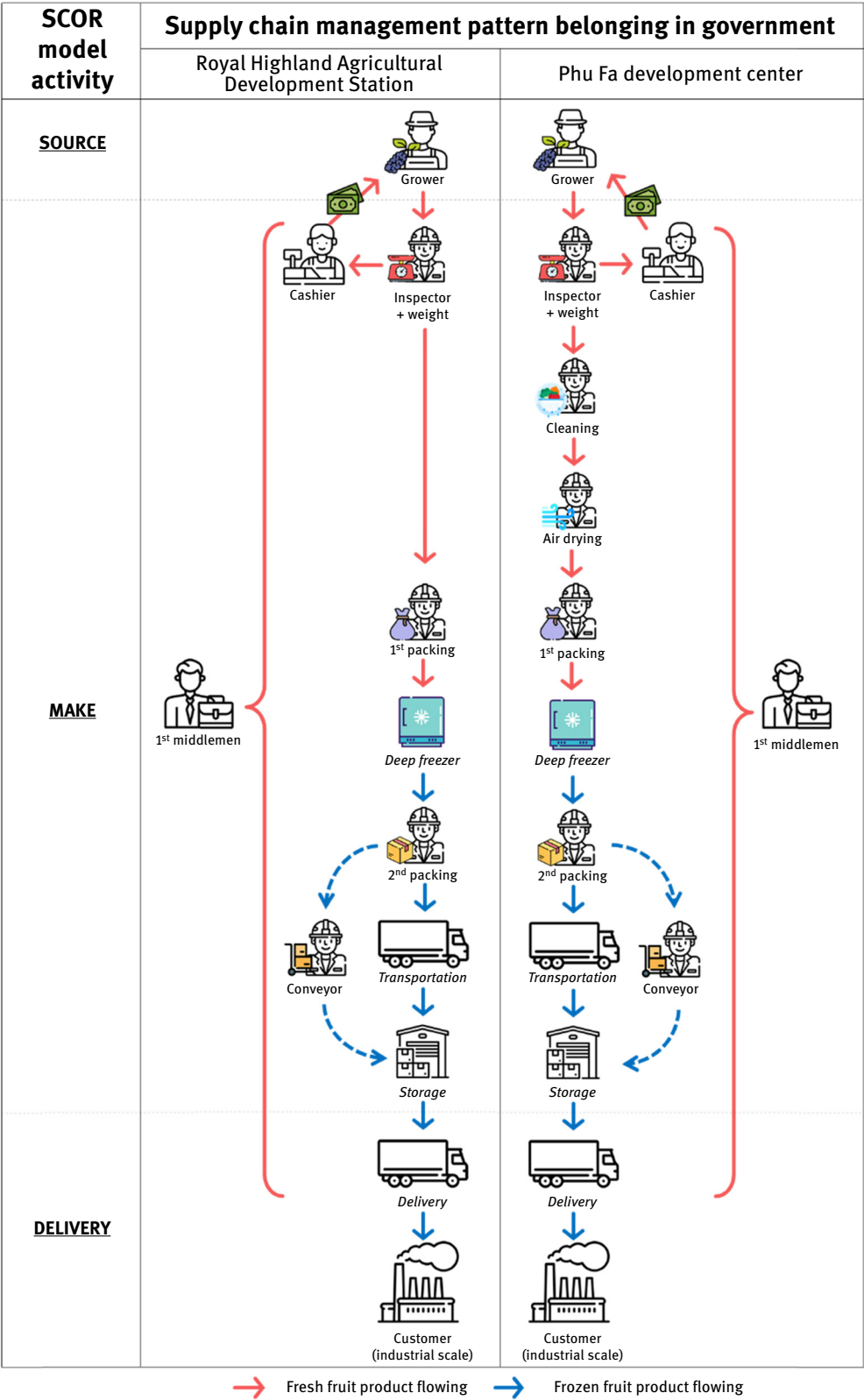


Figure 2: Mulberry supply chain processes at the Royal Highland Agricultural Development Station and Phu Fa development center.

3.3.2.3 Make

3.3.2.3.1 The primary middlemen

At the Royal Highland Agricultural Development Station, the growers carry the fruit to the purchasing point of the middlemen. The appearance of the fruit in the basket is visually inspected to estimate the contaminants and undesirable fruit, such as mold infection, over-ripe, and damaged fruits. If the inspector finds the appearance of the fruits unsatisfied, the fruit basket will be returned to the grower. The fruits can be sent back to the middlemen again, but the growers need to remove the contaminant and other unsatisfied factors. The fruits will then be inspected again. The quality fruit basket will be weighted on a digital balance to be equal to 8.00 kg and then it will be filled into a PE plastic bag about 5.00 ± 2.00 kg/bag. All packs of fruit are kept in a deep freezer overnight. The packing procedure takes approximately 4.00 ± 1.00 min, while the purchasing process takes between 180 and 240 min, depending on the volume of the commodities purchased.

Every second day, two bags of frozen fruit are packed in a carton box and then transported to be kept in a freezer container for 7 days. The frozen products are then shipped to the customers once a week. The carton box loading process takes about 90 min and it takes about 240 min from the loading point to the freezing container, although the distances are only 38 and 53 km away from Phu Pha-Yak and Doi Khun Nan Royal Highland Agricultural Development Station, respectively.

Two additional activities have been added to the Phu Fa development center's process, including two more workers at the cleaning and air-drying sections, but no transportation of fruits is required, as the purchasing point and storage are located in the same place. The fruits will be cleaned by tap water and dried by air blow for 5 min. 2.5 kg of fruits are then packed into a PE bag. Four bags of frozen fruit will be put into a carton box and all boxes will be immediately stored in a freezing storage room.

3.3.2.3.2 The secondary middlemen

The secondary middlemen patterns in mulberry supply chains are exhibited in Figure 3. The secondary middlemen are family businesses with lower human resource costs and lower investment capacity. They use their personal vehicles to buy fresh mulberries directly from their regular growers. They inform us about the purchasing volume and make an appointment for purchasing 1 day

in advance. In Type 1, the fruits are weighed and transferred to the middlemen's plastic baskets at a capacity of 5.0 kg/basket. After that, about 24 baskets are stacked on the backseat of a pickup car (6 columns $\times$ 4 layers of stacking). All the baskets are covered by a wet fabric sheet to protect them from air ventilation and maintain the moisture content of the fruits. During transportation, the air conditioning in the car cockpit is kept at a constant temperature of 25–26°C. All the fruits are sold through several marketing channels such as local markets and contracted customers. In worst case, if the fresh fruit cannot be sold, the unsold fruits are transformed into frozen fruits as a value-added process and the frozen fruits can well serve other customers as well as, exhibited in pattern Type 2. In addition, frozen fruits are also bought from the primary middlemen and the purchasing activities are similar to the fresh fruit purchasing activities as shown in pattern Type 3.

3.3.2.4 Delivery

3.3.2.4.1 The primary middlemen

Stacking 10 kg of fruit per carton box on a truck results in a full truck load capacity of 1.2 and 18 tons for 150 and 240 horsepower trucks, respectively. All the carton boxes are covered by thick canvas to protect the fruit from the uncertain environment and maintain the temperature of the product. The transportation takes about 7–18 h depending on the customer's destination. Also, transportation often takes place at nighttime to avoid the high temperature of the environment that can affect the product quality. The loss of melting products during transportation is about 33.33%. Industrial customers are the main customers of the primary middlemen and they are located in Bangkok, Chiang Rai, Chiang Mai, and Nakhon Pathom. It takes about 7–12 h to ship the products to their destinations.

3.3.2.4.2 The secondary middlemen

A pick-up car is the main vehicle to distribute the products along the supply chain. Fresh fruits in plastic baskets are stacked and loaded into a back seat, while frozen fruit boxes are loaded into the bed panel at the truck bed of the pick-up car, which is covered with a thick canvas. The products are delivered to the customers located in Bangkok, Nakhon Pathom, and Chonburi provinces (central region of Thailand), and it takes about 9–10 h for transportation.

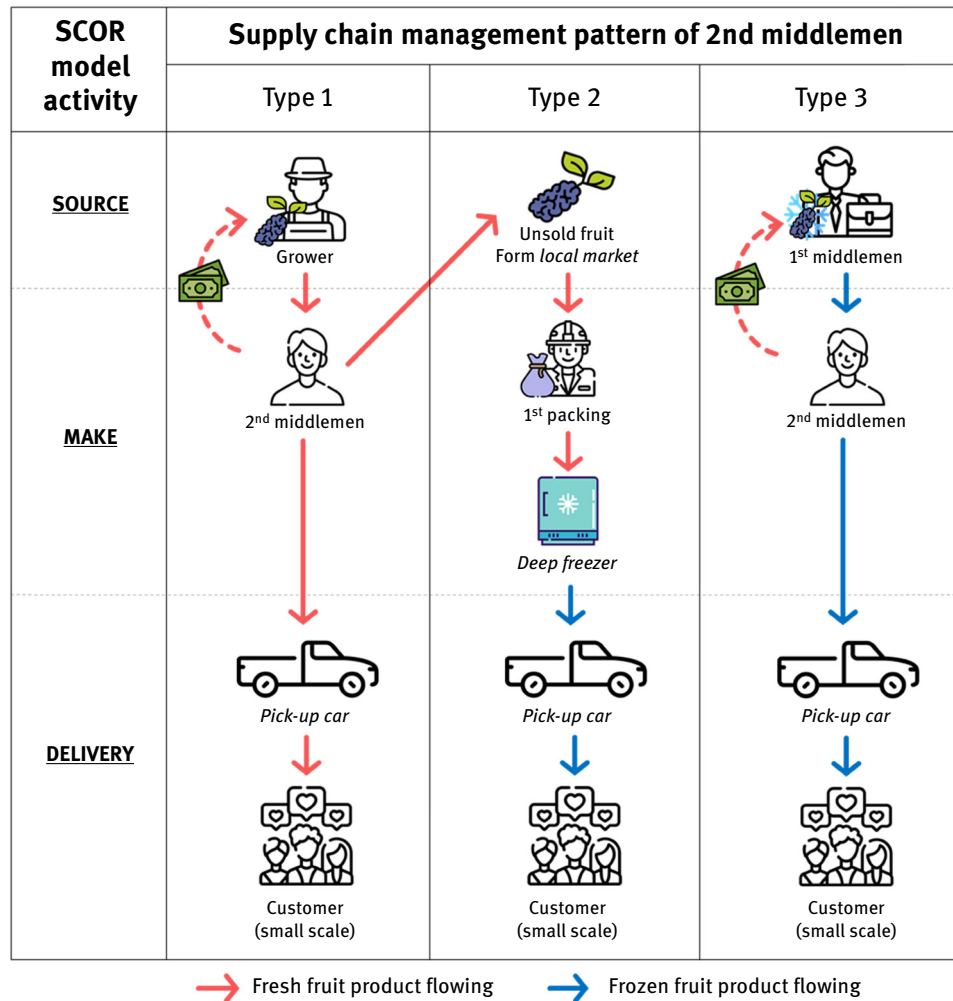


Figure 3: Secondary middle patterns in mulberry supply chain models.

3.3.2.5 Return

At present, the two middlemen do not have a traceability system to track and manage the return of unstandardized and damaged products from the customers. The customers will randomly inspect 10% of the total products to check the quality of the products and packages. If they find that the products do not meet the standard requirements or the packages are damaged and affect the quality of the products, the customers could return all the products back to the seller. However, there has never been such an event.

4 Obstacles in the supply chain

The obstacles of fresh mulberry supply chains can be divided into five categories as follows.

4.1 Product marketing and image

Mulberry fruit is becoming increasingly popular as an exotic functional fruit among consumers because they are highly nutritious and contain a variety of beneficial nutrients such as vitamins, minerals, antioxidants, etc. [28]. Although consumers can access processed mulberries more easily than fresh mulberries because fresh fruits are limited in markets as it is highly perishable and affected by high respiration, high ethylene production, and sugar content enrichment [29]. These factors are often induced by environmental issues such as temperature, moisture content, and cross contamination, leading to shortening of the product life [30–32]. Normally, the mulberries can be stored for a day under room temperature and 3 days in cold conditions.

At present, mulberry fruit is a niche product, especially for a health-conscious customer group. Unsatisfactory physical

characteristics include rough skin and dry pistil covering, which with a lot of hair spread on its surface looks like a slug worm, and might lead to food neophobia [33].

Moreover, mulberry is called as “Mon” in Thai, and the product is often undervalued due to the local name. On the other hand, it will be more valuable if it is called “Mulberry” with the suffix name “berry” because it is similar to other imported berry fruits. In addition, an investigation of mulberry’s price in some Thailand modern trades located in Bangkok was conducted. The price found was high at about 326.00–493.00 baht/kg. The consumer’s demand would be in Bangkok and a health-conscious customer group in major provinces.

4.2 Improper handling

The technical activity consists of harvesting, drying, cleaning, storage, and processing. Mulberry losses can occur naturally (35–50%), followed by product preparation, transportation, storing, and harvesting processes [34]. Some of the growers harvested at the improper maturity stage of fruit due to careless methods. Moreover, mulberry is over-loaded and packed, leading to fruit damage due to mechanical pressing forces. Also, fruit packages were placed in a collection area more than 60 min before transportation.

4.3 Inadequate technological advancement

Using a proper postharvesting method or advanced technology can improve productivity, transportation efficiency, and waste reduction [35]. The frozen fruit selling price of the secondary middlemen was 43.50 ± 4.95 baht/kg and the fresh fruit selling price was 140.00 ± 84.85 baht/kg. However, mulberry is rarely sold as fresh as it rapidly deteriorates within 24 h at the ambient temperature. Nowadays, there are many studies of the storage- and shelf-life extension of mulberry fruits, such as UV-C irradiation [36], sanitizing dipping and fumigation [32,37], and modified atmosphere packaging [38–40], but it was found that these technologies were not yet accessible due to being complicated and costly.

4.4 Transport infrastructure

The transportation route of mulberry from mulberry orchards to the center of Nan takes an average of 6–9 h due to the rough road and high slope. Therefore, the fruits are

damaged and bruised due to the vibration impact. As a result, a large amount of income is lost and people develop a negative attitude towards fresh mulberry fruit.

4.5 Policy ambiguity

At present, 90% of the growers are accredited to GAP standards. The GAP-certified growers are planting the high land and getting support such as mulberry trees and baskets from the two government offices. The purchasing price of the primary middlemen is lower than the secondary middlemen by 35.12%. The certified GAP growers sell their products at a lower price compared to the non-GAP growers in both wholesale and retail sale.

Although the Ministry of Agriculture and Cooperatives of Thailand systematically and continuously encourages orchards to obtain GAP certification to comply with food safety standards for product’s value adding and business confidence enchantment, mulberries harvested from both certified and uncertified GAP orchards are not handled separately. Fruits from GAP certified farms or non-GAP certified farms cannot be distinguished from the viewpoint of consumers as there is no scheme to support or raise awareness of consumers about GAP and food safety. Moreover, the price of the GAP-certified and uncertified fruits is not different.

5 Development of the fresh mulberry supply chain

At present, the frozen fruit is the main product of the traditional supply chain, and the minimum supply chain lead time is 3 days from processing to distribution. However, high risks of this supply chain are presented in terms of electricity uncertainty, insufficient storage space, and order cancelation. There was a personal communication with a government officer who informed that 8 tons of frozen mulberry were lost due to electricity shut down, and it directly affected their income and delivery schedules to customers.

For the modern trade market opportunity for fresh mulberries, it is noticed that retail prices of fresh mulberries are 98.92–99.18% higher than the frozen fruit prices, but fresh product quantities are insufficient to influence the product’s access opportunity for customers. The Sericulture department of Thailand realizes the benefits of this opportunity and encourages the growers and the middlemen to sell fresh mulberry in retail markets as it can increase

income and benefit all the supply chain members especially the hill tribe growers.

To develop a fresh supply chain, the supply chain management of the Phu Fa development center is represented because the growers are GAP certified and it can lead to a good perception for consumers in terms of food safety and hygiene. Moreover, the primary middlemen can sell fresh mulberries to modern trades, and they are flexible in adapting their processes to support fresh mulberry sales. The growers who play an important role as producers in the mulberry supply chain need to pay more attention to harvesting and postharvesting processes according to major requirements in the handbook of GAP for mulberry fruit production, where the harvesting processes should operate under conditions of cleanliness and nourishment [24]. The grower should harvest the fruit by finger picking at the fruit stem. This is the safest harvesting method without any direct impact damage on fruit peel. To reduce compression injury during transportation, the harvested fruit weight should be limited to no more than 2.5 kg in each collecting basket. The fruit basket should not be left in the collecting area (such as the collecting hut) for a long duration. It should be quickly circumvented to the purchasing point or put into the cold chain system to minimize damage influenced by vital and field heat accumulation. However, the growers are not only the producers, they also directly distribute their product to customers as retailers as shown in Figure 4 by using active packaging extending the shelf life, preventing defect occurrences, and improving the fruit quality. The details of the developed active packaging will be provided later.

From the literature, several studies reported the post-harvest technology and applications for maintaining quality and prolonging the storage life of fresh mulberry fruit such as modified atmosphere (MA) packaging [29,41], immersing with aqueous chlorine dioxide [37], coating with chitosan particles [30], and fumigation with active vaporized and gaseous substances such as ozone [32], hydrogen sulfide [42], allyl isothiocyanate [43], 1-methylcyclopropene (1-MCP) [30], and ethanol vapor [31,40]. Ethanol vapor treatment and MA packaging are interesting technologies in terms of ease of use and low cost. They are also reported in many postharvest fruits and vegetables to possibly maintain their quality in various conditions [44–48]. From our previous work, Choosung *et al.* (2019) reported the prototype of active packaging for fresh mulberry fruit in retail sales. The ethanol controlled releasing sachet was combined with an air-tight polypropylene (PP) clamshell box (Figure 5a and b) in which 150 g of fresh fruit was filled. The ethanol vapor

slowly passed through the plastic film to the packaging headspace, the vapor could accumulate and interact with the fruit tissue until the equilibrium was reached. The exceeded ethanol can diffuse into the external environment via the oriented polypropylene (OPP) tape, which was covered between the gap of the lid and the body of the container. The respiration rate and ethylene production of fresh fruit were reduced and the mold hyphae growth was suppressed. Consequently, the fruit senescence was retarded and extended for a 4-day shelf-life at 10°C or the total shelf-life on display is 7 days when compared with fruit packing in a normal package. Moreover, the sweet aroma of mulberry fruit was induced after being exposed to ethanol vapor for the first 24 h, which was indicative of the quality improvement of fresh fruit.

The development of packaging could be appropriate for both the growers and the middlemen, which is demonstrated in the red and green lines of Figure 4, consecutively. This packing method is modified from the field packing process of fresh strawberry, in which they promptly pack the harvested fruit into the final package, and it can decrease the working steps, losses during transportation, and labor costs. The developed independent grower supply chain (Figure 4, green lines) can improve without interrupting the original production process; the collected fruit will immediately be packed in the developed package and this step takes no more than 5 min. The fruit packages can be delivered to a selling area within 1 day. Such procedures should be carried out in accordance with the hygiene of the operator and the cleanliness of the packing area and packaging. On the other hand, the developed packaging can be applied after the fruit drying process at the packing process of the middlemen.

A risk assessment has been conducted based on the questionnaire gathered (Table 3). The growers with traditional practices of postharvesting and handling are used to define the risks of the conventional supply chain, while the risk scoring of the growers with GAP-certified practices is used as a representative of the developed supply chain. For the middlemen, the risk scoring was conducted based on the primary middlemen. The effect of the developed supply chain on the middlemen is a new construction of packaging line including a risk of new marketing channels. A risk comparison between the traditional supply chain and the developing supply chain reveals that the traditional supply chain contains the 7 highest risks, 4 high risks, 7 moderate risks, and 12 low risks, while the developed supply chain contains the 2 highest risks, 12 high risks, 4 medium risks, and 12 low risks. It is noticeable that supply chain development could reduce the total

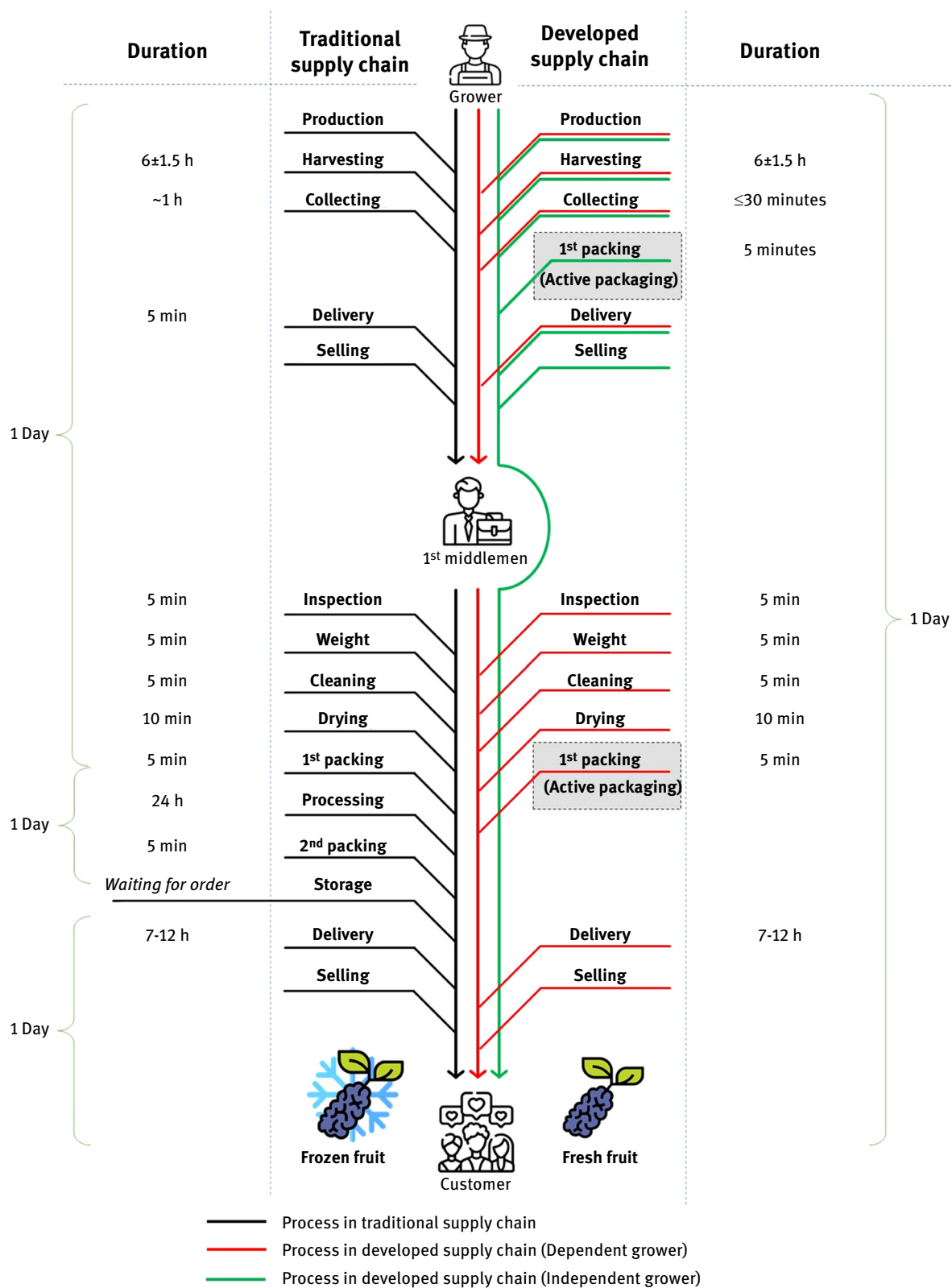


Figure 4: Production and post harvesting practices at the Phu Fa development center.

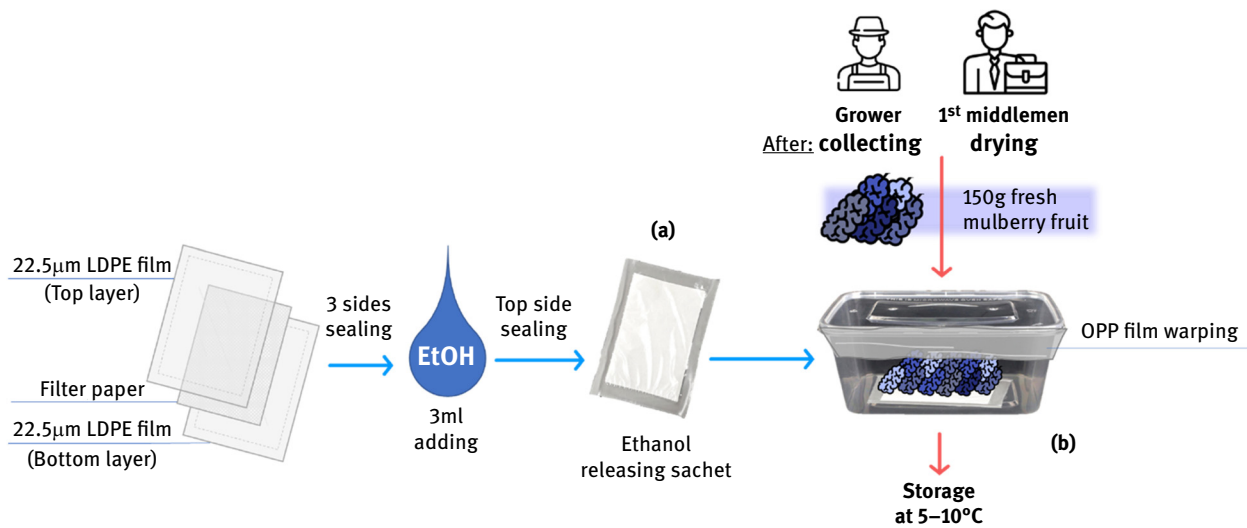


Figure 5: Component of the developed active packaging for mulberry fruit from the previous study [40]. Component of the fruits contained ethanol slow releasing sachet (a) and airtight container (b).

risks by 9.09% as well as the total risks of the growers is decreased by 30.31%. On the other hand, the total risk of the middlemen is increased to 6.87%. The degree of risks for the growers tends to decrease because for joining the developed supply chain, the grower must be certified by GAP standards. Following the GAP standards, all practices will be done correctly and result in lower risks in postharvesting and handling. Currently, more than 90% of the growers are certified. However, there will be an increased risk in handling fresh mulberry in the distribution process. For the developed supply chain with applying the packaging technology, an additional fresh fruit packing process must be added, there may be risks of labor shortages, insufficient conventional cold storage rooms, too high packaging inventory, and rising fuel costs. The developed supply chain can generate more income with a reduction in risks for the growers, while the middlemen can gain more benefits, but at the same time more risks will be faced.

Although more risks will inevitable for the primary middlemen, improving the quality of life and occupation of hill tribes in the highlands is one of the Thai government's policies. The Office of the Royal Development Projects Board, a non-profit organization, has directly supported the budget for the operation of The Royal Highland Agricultural Development Station and Phu Fa development center which acts as a "primary middleman" in the fresh mulberry fruit supply chain [49]. As per the State Fiscal and Financial Disciplines Act, B.E.2561 (2018) in Section 28 defines that the government bears the burden of reimbursement for expenses or loss of revenue in the operation of government agencies to revitalize or stimulate

the economy or to increase the capacity for occupation or to improve the quality of life of the people or to help rehabilitate those affected by disasters or sabotage [50].

In terms of cost and time comparison, the traditional and developing concepts of supply chains stimulated are shown in Figure 4 which refers to the analyzed cost data from the report of Nopparat *et al.* [51] exhibited in Table 4. The lowest cost of frozen mulberry being sold to the processing factories at the traditional supply chain structure is 23.89 baht/kg, and the lowest selling price is 3.50–4.00 baht/kg as well. While the developed supply chain models can increase the selling prices by up to 326–493 baht/kg for fresh mulberry sales, the costs vary based on whether or not the supply chain structures have primary middlemen. A major direct cost of the developed supply chain is the developed active packaging cost as it is about 74.63 baht/kg or 11.19 baht/kg and one mulberry pack contains 6.67 kg. The management cost of the developed supply chain dependent on having middlemen will be increased by 74.63 baht/kg or 312.39% and the selling price will also be increased by 98.92–99.18%.

On the other hand, total time to customers will be reduced by 55.45–62.93% and it can increase inventory turnover to improve working capital for the supply chain. To use the active package technology in the supply chain with having middlemen, those middlemen will be responsible for finding customers that can be Business-to-Business (B2B) and also Business-to-Consumer (B2C). For B2B, there is a high possibility of increasing the sales volumes as modern trades and royal shops such as the Phu Fa shop or the Royal Project shop would like to have fresh mulberries in their shops and they have tried to sell

Table 3: The risk assessment comparison between traditional and developed fresh mulberry fruit supply chain

Supply chain member	SCOR model	Risk details	Supply chain type (score)					
			Traditional			Developed		
			Impact	Likelihood	Risk	Impact	Likelihood	Risk
Growers	Plan	Lack of production knowledge	2.67	1.26	3.36	1.13	1.09	1.22
		Yearly projected purchase/production volume is unknown	1.21	1.70	2.05	1.20	1.26	1.51
	Source	Did not receive sourcing plan from government officers	1.18	1.35	1.59	1.17	1.13	1.32
		Growers had not registered with government officers yet	2.52	3.35	8.44	1.21	1.23	1.49
		Lack of planting utilities from middlemen	1.27	1.43	1.82	1.18	1.04	1.23
Middlemen	Make	Did not prepare planting utilities and areas according to GAP standards	3.98	4.22	16.78	1.15	1.00	1.15
		Prices of production utilities were risen	4.16	3.22	13.37	4.73	2.17	10.29
	Delivery	Fruit was harvested with carelessness	4.79	4.57	21.86	4.80	2.78	13.36
		Harvested fruit are of poor quality (nonuniform maturity, contaminated, and damaged fruit)	4.62	4.35	20.10	3.86	3.74	14.43
		Producing more than purchasing volume	4.88	4.43	21.63	3.31	4.13	13.67
	Return	Improper handling and too long transportation time	4.90	1.17	5.75	3.54	1.13	4.00
		The product is damaged during transportation	4.70	1.26	5.93	3.70	3.30	12.24
	Plan	The product was returned due to poor quality or damage	4.68	1.09	5.08	3.72	4.48	16.65
		Lack of communication about volume of purchases/sales between members in the supply chain	1.00	1.67	1.67	1.00	1.00	1.00
		Price drop	3.67	3.33	12.22	3.67	3.33	12.22
Growers	Plan	Lack of purchasing commercial term and condition of customers	1.67	2.67	4.44	1.67	4.33	7.22
		Lack of knowledge about the fresh mulberry market	1.33	2.33	3.11	1.33	2.33	3.11
	Source	Shortage of planting utilities	1.00	1.00	1.00	1.00	1.00	1.00
		Prices of planting utility were risen	2.00	1.33	2.67	2.00	3.33	6.67
		Unequal distribution of planting utilities for growers	1.33	1.00	1.33	1.33	1.00	1.33
	Make	Labor shortage	3.33	2.00	6.67	2.33	4.33	10.11
		Labors' lack of proper postharvest knowledge and practices	4.00	3.67	14.67	3.33	3.00	10.00
		Lack of quality cold storage and storage space	5.00	4.67	23.33	1.67	1.67	2.78
	Delivery	Too much inventory on hand/oversupply	5.00	4.67	23.33	2.67	3.00	8.00
		A backup power source is insufficient to keep or maintain cold temperature for fruit	3.67	5.00	18.33	3.67	4.00	14.67
Middlemen	Plan	Unclear marketing advertising and promotion	4.67	3.00	14.00	3.67	3.33	12.22
		Too much packaging stock	1.00	1.00	1.00	5.00	4.00	20.00
	Delivery	Improper handling and too long transportation time	2.33	2.33	5.44	1.67	3.67	6.11
		Fuel prices increasing	3.67	2.33	8.56	4.33	5.00	21.67
		The product was returned due to poor quality or damage	1.00	1.33	1.33	3.33	4.67	15.56

Table 4: Cost and time of traditional and developed supply chains

	Unit	Traditional supply chain	Developed supply chain	
			Dependent grower	Independent grower
Grower's cost	baht/kg	12.19	12.19	86.82
Middlemen's cost	baht/kg	11.70	86.33	—
Total cost	baht/kg	23.89	98.52	86.82
Type of product	—	Frozen fruit	Fresh fruit	Fresh fruit
Selling price	baht/kg	3.50–4.00	326.00–493.00	326.00–493.00
Total time to customers	h/kg	42.83 ± 1.50	19.08 ± 1.50	6.68 ± 1.50

fresh mulberry, but the limitations of the mulberries are the major obstacles. Moreover, the middlemen have enough mulberry to fulfill the demands of modern trades and the mentioned shops as well as good practices in terms of logistics management. For B2C, it is easy to establish an online market platform and send products via express logistics services. For the independent grower, only direct sales to consumers can be conducted. To establish this type of model, the growers need to establish an online market platform. Harvesting must be matched with customer demand and logistic practices must be improved to assure that the growers can satisfy customers according to cost, time, and quality.

It can be seen that packaging plays an important role in connecting with other activities, including marketing, production, and logistics. The function of packaging is related to the product, which should not have a negative impact along the supply chain [52]. The advantage of the development of the supply chain via the upgrading technology has 4 dimensions: 1) offering new distribution channels to increase profit, 2) reducing the management cost and time, 3) increasing product value, extending the product life, and reducing product losses, and 4) ease of accessing the product with a convenient package, and they are impressed with the products, encouraging repetitive purchases.

6 Recommendation

One unit of 10 kg of frozen mulberries can be sold for 35–60 baht, while 10 kg of fresh mulberries packed into 150 g boxes (approximately 67 boxes) can be totally sold for 2,260–3,720 baht (225–370 baht/kg). The new development of fresh mulberry sales can be created with the use of the new dimension of aromatic sensation stimulated by the ethanol vapor as it can prolong the shelf life of mulberries at display temperature (5–10°C). An increase

in income from selling fresh mulberries to growers contributes to better household economics and reduces shifting cultivation and deforestation.

COVID-19 global pandemic situation has affected the lifestyles of human beings around the world and the global economy. The forecast of major economies' losses in 2020 is predicted at 4.5% of their GDP [53]. Grocery stores and supermarkets are impacted by the hours of operation and the extent to which customer access is restricted in accordance with public health policies aimed at reducing the risk of infection in crowded locations. Online e-commerce platforms are used as an additional channel to facilitate customers. Customers can buy products with no restrictions on time and place. In Taiwan, the usage of food service and delivery applications such as Uber Eat and Food Panda rose by 20–30% during the pandemic. Moreover, Taiwan's Council of Agriculture created "Ubox" platform for selling food and related products from individual and/or small farm directly to the customers, protecting them from the loss of income during pandemics and other times, while the customers receive high-quality products directly from the producers [54].

The online e-commerce platform could be applied to fresh mulberry fruit distribution during the pandemic, and it could continue as the lifestyle of customers has changed from off-line to on-line marketing. The customer possibly uses the available online e-commerce platforms in Thailand, such as Shopee, Lazada, and other delivery platforms. Shopee and Lazada platforms play a role as a pure-play e-grocery model in which they have an online virtual storefront that can combine multiple vendors in multiple locations. The vendor can reduce inventory holding costs and increase inventory turnover rates, which helps them decrease product loss yield and delivery duration. However, the problem of perishable fruit or vegetable shipment was limited due to the high cost of cold chain management. Bulk shipping at wholesale is more cost-effective. In addition, door-to-door delivery companies, such as SCG Yamato Express and Inter Express Logistic,

have developed a temperature-controlled shipping method to deliver fresh products using cold boxes that can be set at 0–8°C for chilled products such as fruits, vegetables, and meat, and –15°C or below for frozen products. The customer is guaranteed to receive their products within 2 days with the nationwide service. Thus, the logistics service providers are an important part in connecting the growers with the consumers.

High competitive businesses, packaging design, and development are realized to be one of the marketing tools used to attract customers to earn more profit [55]. Since packaging is the first attraction that consumers can see before touching the inside of the product, it can motivate consumers to buy. Most producers spend a lot of time making their packaging stand out, communicating the information and strengths of their product's image. In addition, the useful information should be labeled on the package which is another practical and powerful marketing tool to make a good perception on customers [56,57]. Important information on the package should include product name, nutrition value, producer name, producer contact details, product volume, date of manufacture and expiration, instructions for use, standards or certification, and bar coding to provide track and traceability. Additional information indicating the strengths of the product in terms of social and environmental concerns can be added such as environmentally friendly products, organic products, or promoting the well-being of people in the production area, etc.

7 Conclusion

The supply chain structure of mulberry fruit in Nan province can be classified into four patterns. The primary middleman is the key actor who potentially drives the supply chain. Growers typically play the producer role, and some of them in the plateau cultivation areas have geographic advantages, so they occasionally act as a dealer or distributor. Although most of the growers were encouraged to practice to get a GAP certification, they could not receive a significant benefit from the certificate as there was no difference between GAP's price and non-GAP's price. Frozen mulberry is the main product of the current mulberry supply chain due to the natural characteristics of the mulberry. The major obstacles to the mulberry supply chain include product marketing and image, improper product handling, technology advancement, transport infrastructure, and policy ambiguity. The results of the study led to the stimulation of the

development of fresh mulberry supply chain models. The active package technology can be utilized to support the B2C and B2B trades in fresh mulberry. As a result, the supply chain can gain more benefits and share profits with the growers. At the same time, consumers can get mulberries with good quality and safety and with high nutrition as well.

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