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The cold chain of golden apple snail: A case study

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Abstract

Cold chain management is a necessary part of reducing food loss and maintaining food safety in production, storage, and distribution activities along a supply chain. However, the adoption of cold chain logistics by Thailand's agricultural and food sectors remains underdeveloped. The golden apple snail supply chain is an important part of the economy in Northeast Thailand, however, it is facing losses due to food waste. Consequently, this study aims to analyse supply chain operations and propose guidelines that help reduce food loss towards building an unbroken cold chain. A case analysis at Baan Huakwa, Kalasin, one of the main golden apple snail storage facilities, was selected as a starting point for the snowball sampling technique used in this cold chain study. Following an assessment of current cold chain management practices at the facility, a supply chain operations reference model and value chain were used to systematically suggest possible improvements. The study found that this specific cold chain breaks during transport from the snail farmers to the storage/packaging facility. It also found that a lack of control over the environment and a lack of product forecasting sometimes lead to snail shortages or oversupply. Furthermore, the length of delivery and amount of time stored at improper temperatures with the use of only an ice cooler and pickup tarpaulin can result in spoilage. The option of investing in temperature-controlled trucks is considered. This study provides key recommendations for relevant stakeholders to enable them to implement the changes necessary to improve the existing cold chain system. This study can be further applied as a reference for perishable food supply chains.

Keywords: Golden apple snail, Perishable food, Cold chain, Green logistics, Kalasin

1. Introduction

1.1 Background

The geography, topography, and climate of different regions impact food production; certain conditions must be met for food to be successfully produced. Food production entails various processes including transport from farms to storage facilities and trade by distributors before arriving at the market. Transportation is an important part of the food distribution supply chain. Transportation infrastructure limits the efficiency of food distribution in many developing countries [1, 2].

Approximately 15-45% of food is lost or wasted [3]. There are many causes of food loss/waste, such as poor production, lack of storage capacity, lack of proper transportation, lack of knowledge regarding the handling of perishables, food being thrown away or left uneaten, as well as a decrease in quality and quantity of food along the supply chain [4]. Food, especially perishable, mainly deteriorates due to the temperature and waiting time. This results in economic losses that are related to issues of resource usage and environmental impacts. The use of improved harvesting, processing, and storage techniques, including energy-efficient cold chains, could be employed to reduce food loss in supply chains [5].

A food cold chain is a refrigerated supply chain that is used to maintain and preserve the integrity, freshness, and quality of perishables through a series of operations from the point of origin to the point of consumption [6, 7]. Cold chain management is necessary for reducing food loss and maintaining food safety in production, storage, and distribution activities along the supply chain. However, the adoption of cold chain logistics in Thailand's agricultural and food sectors remains underdeveloped. There are currently 664 temperature-controlled warehouses and 371 temperature-controlled vehicle services available with Bangkok, Central region, and Southern region having the highest level of investment in cold storage industries [8].

The golden apple snail has an important role in the economy in the Northeast of Thailand. It can be an ingredient in a number of popular north-eastern Thai dishes. The market price for golden apple snails is around 60-80 baht per kilogram. This can generate revenues of 400-500 baht per day for snail farmers/catchers and more than 100,000 baht a month for the middleman. However, the golden apple snail supply chain faces problems due to potential food waste and economic losses. More specifically, in this case study, it was found that approximately 20% of the product transported downstream is damaged or spoiled and requires a refund. There is a

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demand for efficient cold chain logistics and storage. Consequently, this study aims to understand current golden apple snail supply chain operations, investigate this supply chain's cold chain management, and propose guidelines that help reduce food loss by developing unbroken cold chains.

1.2 Theory and literature reviews

1.2.1 Logistics and supply chain management

The supply chain operations reference model (SCOR model) as shown in Figure 1 introduces the integration of concepts related to business process reengineering, performance measurement, and logistics management into a configurable, cross-functional framework. The four levels of this model are as follows [9]:

- Level 1 outlines the critical supply chain processes of planning, sourcing, making, delivering, and returning. It helps businesses in setting supply chain management goals.
- Level 2 explains the primary process types seen in both real and fictitious enterprise supply chains. Examples include 'source stocked products', 'source make-to-order products', and 'source engineer-to-order products'.
- Level 3 contains data that the supply chain management team can use to acquire products and set targets for its supply chain management strategy. Definitions, benchmarks, and system software capabilities are also included in this.
- Level 4 is implementation. The specific elements of level 4 are not described in the SCOR model because supply chain management solutions vary from company to company.

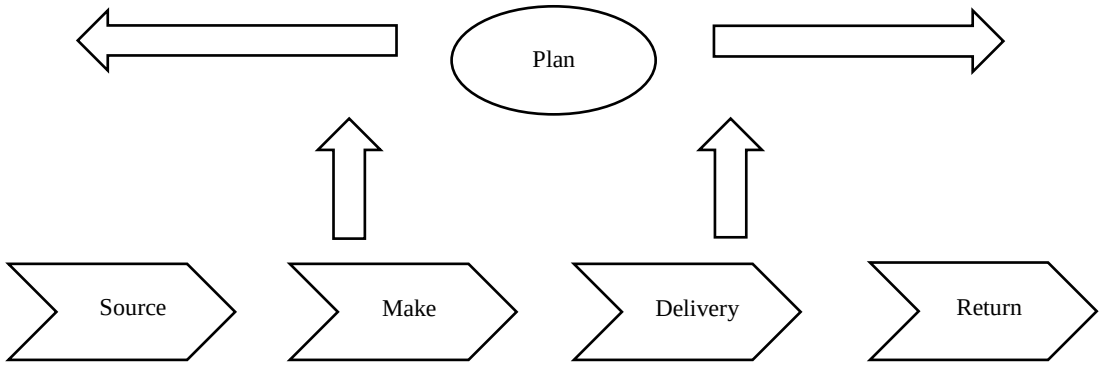

Figure 1 SCOR model

The value chain is a series of value-creating operations [10]. At various points, every activity makes a difference in the generation of added value. The analysis will highlight the advantages and disadvantages of each activity. The value chain can be broken down into five major activities that include (1) Inbound logistics which is an endeavour to use inputs, (2) Operations which is an activity involved in transforming raw resources into finished commodities, (3) Outbound logistics which is a task involved in the distribution, collection, and storage of goods and services for customers, (4) Sales and marketing which involves attempts to persuade customers to purchase products and services, and (5) Customer support which is a service that deals with maintaining or adding value to products. The value chain also comprises four supporting activities and after-sales services that include (1) Business facilities which is a broad administration-related activity, (2) Management of human resources which is a human resource management-related activity, (3) Advancement of technology which is an activity that enhances the worth of a good or service, and (4) Purchasing procedure which is an action that involves buying and obtaining resources to be used in carrying out various activities.

1.2.2 Food cold chain

A cold chain begins from either the time of harvesting or from the time of processing [11]. Temperature is the core function of a food cold chain because it is used to maintain the shelf-life of a product. Temperature ranges may vary depending on whether a product is classified as frozen, cold chill, medium chill, or exotic chill [12].

The main elements of a cold chain involve [13]:

- Cooling systems that bring perishables to the appropriate temperature for processing, storage, and transportation.
- Cold storage that provides facilities for the storage of perishables over a period of time.
- Cold transport that provides a means of moving perishables under stable temperature and humidity conditions.
- Cold processing and distribution that provides facilities for the processing of perishables as well as consolidating and deconsolidating loads for distribution.

A cold chain service can be offered by precooling, temperature-controlled warehouses, and temperature-controlled transportation. For cold chain, its management and performance measurement are challenging due to products shelf-life, products safety, physical properties of products, production time, production period, type of transportation, storage conditions, and environmental conditions [14]. As a result of those complexities, it can be difficult to identify where, when, and how a product is damaged [15]. The concept of a food distribution supply chain and transport is shown in Figure 2.

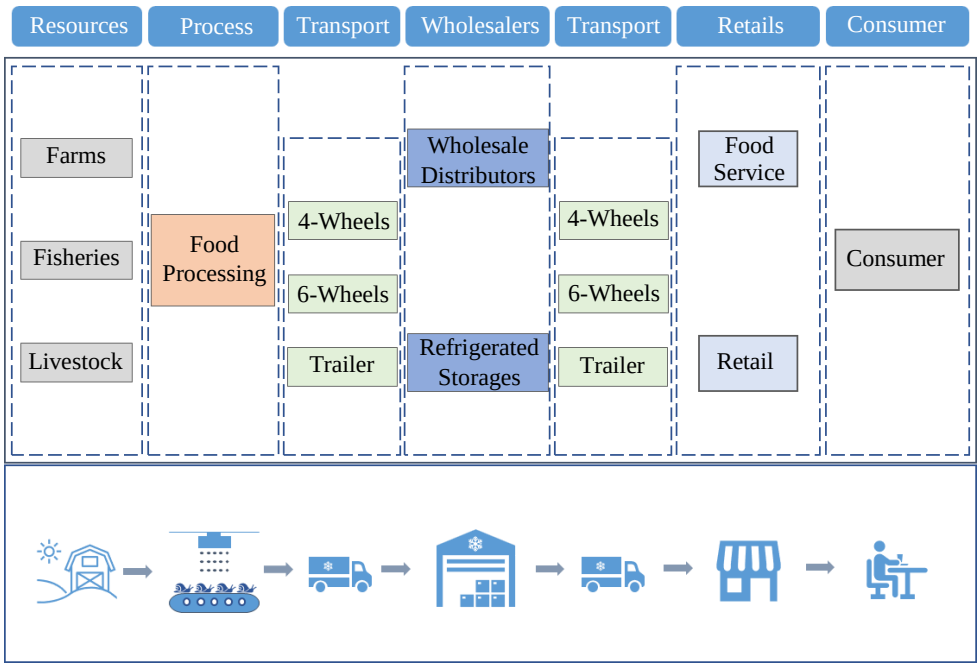

Figure 2 The concept of the food distribution supply chain and transport. Adapted from Thornton J. et al. [16]

Risks related to the quality and safety of perishables in a food cold chain can be reduced by implementing worker training, recording acceptable product temperatures, setting real-time temperatures, and using alarm systems [17]. The service level for a cold chain includes providing customer delivery services that use cooling systems, company operating hours tailored to customer needs, and local company premises for all levels of customers so that the transportation distance is relatively short [18].

Optimising cold chain logistics for fresh produce can be achieved by implementing three important aspects that include (1) Improving the efficiency of cold chain logistics via cooling rate, cooling uniformity and stability, and packaging design, (2) Ensuring the integrity of the cold chain and its precise control through dynamic monitoring and shelf-life prediction, and (3) Promoting the cold chain's ecological and sustainable development through reducing energy consumption, increasing cost savings, and minimising environmental impact [19].

For efficient improvement in cold chain logistics, tracking and tracing system are required. Technologies such as battery-free sensing systems [20, 21] can be used for this purpose. The appropriate planning of distribution networks, vehicle routes, or vehicle schedules is another approach currently used to improve food supply chains [22] alongside the application of geographic information system (GIS) [23-25] or the consideration of carbon emissions [26-28]. These improvements can reduce food loss in transportation and improve the efficiency of green logistics operations. In addition, mode of delivery for time-sensitive products should be considered in cold chain shipping [29].

For efficient and sustainable transportation, no single vehicle is suitable for all types of goods or raw materials. The choice of the most appropriate cold chain transport vehicle depends mainly on specific circumstances, such as transport temperature which is a key factor in keeping raw materials fresh [18, 30, 31], tracking systems that keep track of delivery status at all times (e.g. tracking air and product temperatures in a refrigerated truck) [20, 21, 31, 32], cold traceability that checks for possible errors along the supply chain [18, 20, 21, 31-34], fuel type that determines the costs incurred [35], environmental impacts caused by transport that contribute to sustainability in the cold chain industry [26-28, 31, 36], transport costs that are associated with initial investment [18, 30, 31], distance travelled proportional to costs [22-25, 31, 36], and the quality of goods at the destination [18, 31].

Based on reduction, reuse, and recycling principles in a circular economy, factors which affect the development of the green logistics of agricultural products include, for example, vehicle exhaust emissions and waste recovery rates [37]. For developing countries, the enablers and the barriers to adopting cold chain services among providers are addressed in [38]. The possible enablers include income diversification, higher profit margins, customer demand, company expertise, and resource availability. The barriers may include cost, lack of expertise and resources, customer location, and lack of government support. These issues should be addressed to promote the adoption of cold chain services.

In Thailand, it was found that insulation installation in cold storage rooms, construction of anterooms for goods prior to entering the cold storage room, 20-30 minutes of precooling before transport, and reduction of door openings/closings are required for Japanese restaurant cold chains [39]. Furthermore, cold chain management for perishables at green market in Thailand was studied using a SCOR model and supply chain risk management [40]. These data support the view that cold chain management must be considered.

2. Materials and methods

This study uses a snowball sampling technique because it enables the discovery of hidden populations. Snowball sampling is a nonrandom sampling technique that can use existing study participants to recruit new participants. A case analysis at the Baan Huakwa storage facility, one of the main golden apple snail storage facilities in Thailand, located in Kalasin Province, was selected as a starting point in snowball sampling technique used in this cold chain study. Information obtained from in-depth interviews includes sale revenues, storage methods, transport methods, customer details, loss of goods, location of supplies, and harvest methods which were

then analysed according to the study's objectives. This study provides a descriptive analysis of cold chain logistics using data collected from snowball sampling. Following an assessment of the current cold chain management, a SCOR model and value chain were used to systematically analyse operational efficiency and provide possible improvements, respectively. The research framework for reducing loss and waste in golden apple snails is shown in Figure 3.

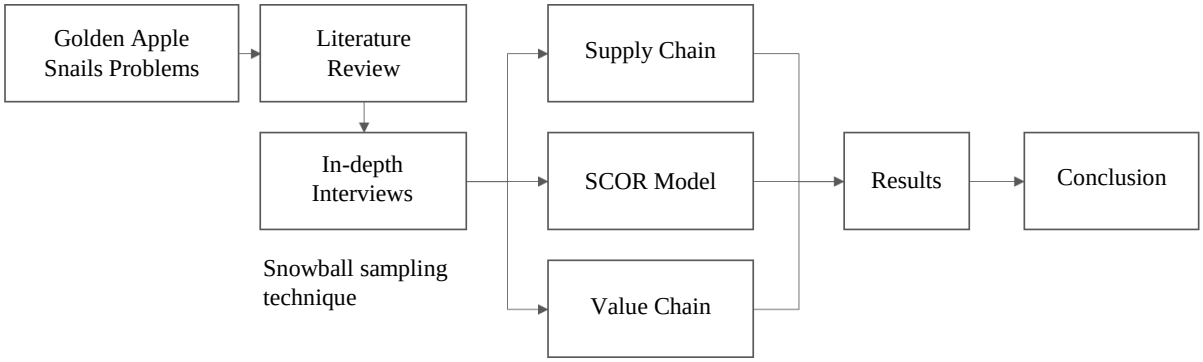

Figure 3 The Golden apple snails research framework

3. Results and discussions

3.1 Supply chain of golden apple snail in Northeast Thailand

Figure 4 depicts upstream, midstream, and downstream sections of the golden apple snail supply chain in Northeast Thailand. In the upstream of the supply chain, the operation process includes harvesting the golden apple snails from the source and storing them, and then, within a few hours of the harvest, transporting the snails in a box to the middleman by using either motorcycle or pickup truck with a tarpaulin cover. In the midstream of the supply chain, the middleman buys the snails and transports them to a warehouse with ice-cooled storage units waiting for the incoming shipment. At the downstream section of the supply chain, the key activity is to arrange the delivery by a pickup with ice coolers and pickup tarpaulin to the central market, individual consumers, or north-eastern Thai restaurants that need the snails for their catering.

From this analysis, a flow of incomplete information can be seen along the supply chain. The missing information includes customer demand, golden apple snail supply, and delivery of orders. Food loss is another significant problem found in the chain. As perishables, golden apple snails are prone to damage throughout the supply chain. The spoiled resources can be found in three activities along the supply chain.

In the upstream activity, the natural environment affects the growth and propagation of golden apple snails. The exact quantity required by customers each time cannot be predicted. As a result, the supply sometimes does not meet the demand. Therefore, it is necessary to practice longer storage times during shortages. During the rainy season, golden apple snails reproduce and grow quickly such that the available quantity happens to exceed order requirements. However, some of the golden apple snails might become damaged due to the use of non-temperature-controlled storage.

In the middle stream activity, the middleman purchases resources from suppliers or farmers who send orders 3-4 days in advance. Because of this rapid flow of information between partners, the suppliers do not stock seasonal goods. This affects the ability of suppliers or farmers to keep up with demand. Furthermore, damage caused by shipping without temperature control often occurs during transportation to the warehouse. The storage of raw materials waiting for the next transport can also be affected due to the use of equipment that is not meant for temperature-controlled storage. Depending on the temperature requirements for the chilled aquatic products, medium-temperature cold air storage (from -5 to 5 degrees Celsius) is suggested [19].

In the downstream activity, the final stage, the perishables are transported by pickup trucks. Owing to uncertain delivery times and distances, distribution is sometimes delayed and unpredictable. Transportation routes are frequently changed to accommodate drop offs for multiple orders. Therefore, the delivery could take up to 20 hours with the snails stored in an ice cooler at about 13 to 15 degrees Celsius. As a result, the product is frequently damaged due to the use of non-standard temperature-controlled road vehicles. Raw materials become spoiled at times when there is no recipient. In this case, this waste must be disposed of at the destination and the middleman must provide a refund equal to the amount damaged.

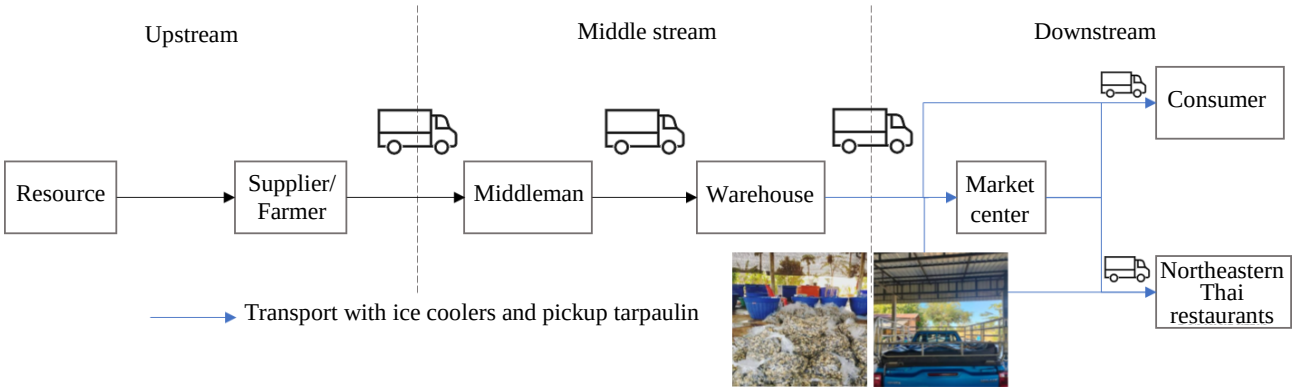

Figure 4 Golden apple snail supply chain in Northeast Thailand

The golden apple snail supply chain described above is a combination of three linked systems that consist of ice storage, ice transport, and marketing. When considering a complete cold chain logistics system for aquatic products [19], precooling is missing.

3.2 Cold chain transportation

A common method for transporting chilled or frozen fishery products, including golden apple snails, is to use a pickup truck with an ice bucket that acts as a container to keep the produce cool. The efficiency and sustainability of this transportation depend on many factors including temperature [18, 30, 31], tracking [20, 21, 31, 32], traceability [18, 20, 21, 31-34], fuel [35], environment [26-28, 31, 36], cost [18, 30, 31], distance [22-25, 31, 36], and product quality [18, 31]. Table 1 shows the advantages and disadvantages of using a conventional truck to transport products over long distances. The damage or spoilage of goods during transportation causes the cost of resolving this issue. Table 2 shows the advantages and disadvantages of choosing a refrigerated truck to solve such problems.

Table 1 The advantages and disadvantages of using conventional trucks to transport chilled, frozen food

Category	Advantages	Disadvantages
1. Temperature	Save the installation cost of temperature-controlled equipment for transportation within 1-2 hours.	Unable to control temperature.
2. Tracking	Able to track the status of the shipment when a tracking system is installed in the transport.	The budget for investing in the global positioning system (GPS) is quite high, not suitable for small business investments.
3. Traceability	Transport traceability can be traced back when the tracking is installed on the vehicle.	It is used in conjunction with the tracking system for tracking and monitoring.
4. Fuel	Able to choose fuel that is suitable for transportation.	The cost of fuel fluctuates due to a volatile market, making it difficult to control costs.
5. Environment	Able to choose to use an appropriate vehicle that supports alternative energy as a fuel and reduces greenhouse gas emissions.	Empty back-haul is also a major problem in emissions during transportation.
6. Cost	The cost of investment in buying a car is ideal for small businesses.	There is a transportation fee, especially the cost of fuel, various lubricants, and maintenance costs.
7. Distance	Suitable for transportation within 1-2 hours.	Long-distance transportation causes damage to perishable products.
8. Product Quality	A variety of refrigeration equipment can be used for transportation as appropriate.	Storage time during transportation depends on the cooling equipment used.

Table 2 The advantages and disadvantages of using refrigerated trucks to transport chilled, frozen food

Category	Advantages	Disadvantages
1. Temperature	There is a temperature control system that is suitable for the type of product.	Cooling efficiency of cold room cabinets depending on the type of product placement.
2. Tracking	There is a GPS device installed in the vehicle for use in identifying different states.	Some devices cannot track driver behaviour during transportation.
3. Traceability	Able to check the transportation retrospectively if the goods are damaged.	The stability of the programme used to monitor.
4. Fuel	Able to choose fuel that is suitable for transportation.	The cost of fuel fluctuates due to a volatile market, making it difficult to control costs.
5. Environment	Technology has been developed to control greenhouse gas emissions in an appropriate amount.	Empty back-haul is also a major problem in emissions during transportation.
6. Cost	It is a one-time investment in equipment used to control the cooling.	There is a transportation fee, especially the cost of fuel, various lubricants, and maintenance costs.
7. Distance	Can be transported at any distance.	Driver fatigue when delivering goods over long distances.
8. Product Quality	There is little or no damage to the product caused by transportation.	It depends on the layout of the product to get the right temperature.

As a major problem in this cold chain, the spoilage of golden apple snails during transportation is one of the factors that increase logistics costs. In this case, the cause of the problem is the use of conventional pickup trucks that carry ice coolers and cover the bed with tarpaulin for transport in the downstream section of the chain. To solve this problem, a standard temperature-controlled truck could be used to maintain the freshness of the produce during transportation.

Initial investments for different alternatives of temperature-controlled trucks are shown in Table 3. From the calculation, the payback periods for standard truck and temperature-controlled trucks differ slightly. The cost-effectiveness of this investment reduces the logistics cost caused by material damage. Therefore, another worthwhile investment that might aid in preventing the spoilage of perishables is the conversion to temperature-controlled trucks.

Table 3 The investment of temperature-controlled trucks

Activities	General Pickup Truck *	4-Wheel Refrigerated Truck **	6-Wheel Refrigerated Truck***
	Diesel	Diesel	Diesel
Truck Price (Baht)	607,000	598,000	1,224,000
Gross Weight (Tons)	1.1	1.1	5
Temperature Control (°C)	-	+25, -18	+25, -18
Lifetime (Years)	3-5	3-5	5-7
Payback period (Years)	1.12	1.10	2.27

Note: *ISUZU D-Max Spark Price from ISUZU in 2020
** Price from iColdCar in 2021
*** Net Profit = 540,000 Bath/year; source by the authors

It is recommended to switch from the current practice of ice transport to refrigerated transport. A refrigerated vehicle will improve food safety and supply chain effectiveness across long distances [39]. This suggestion is in line with the study presented in [19], which suggested that applying technology and improving equipment in cold chain logistics can improve the efficiency and sustainability of cold chain logistics.

3.3 SCOR model

Figure 5 illustrates plan, source, make, deliver, and return activities along the golden apple snail cold chain. Level 1 processes in the SCOR model are considered. In the planning process, suppliers/farmers, the middleman, or both (i.e., intra-supply chain planning) do not account for either short-term or long-term storage. This makes the prediction of demand impossible when only consumer orders are observed. As a result, there is currently excessive or inadequate storage of resources.

In the sourcing process, the supply of golden apple snails is frequently insufficient since the production mostly depends on the environment. To source quality golden apple snails that meet the standard specified by the retailer, the middleman must set a clear purchase price based on quality and seasonality. The source of the golden apple snails should be cleared of any backlogs prior to the next round of shipments.

In the making process, delivery routes must be scheduled and an appropriate transport packaging for raw materials must be designed to improve the efficiency of transport under controlled temperatures.

The middleman has employed a third-party logistics (3PL) provider for the delivery activity. It was discovered that the merchant had previously been unable to find, trace, and track the location of the 3PL vehicle. Due to the carrier's unknown transportation route and inability to predict the length of time and the distance travelled, delays in receiving the products resulted in waiting times. The appropriate temperature was not maintained during the loading and unloading of the perishable items. This inflicted considerable damage to storage locations including provincial markets and customer warehouses.

For the return activity, the middleman occasionally has issues with receiving the returned items. If the item is damaged or rotten, the sellers are willing to issue refunds. However, goods must be examined before being sent back or destroyed.

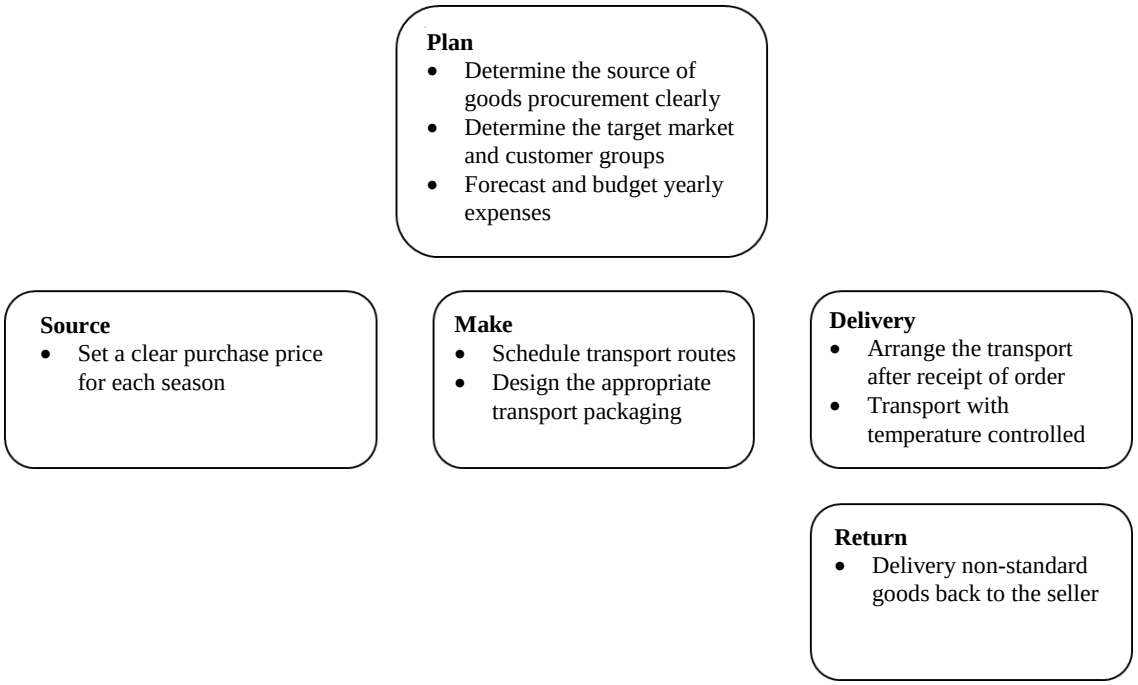

Figure 5 SCOR model of golden apple snail supply chain

The SCOR performance provides stakeholders with information on losses brought on by the current supply chain and offers a chance to improve business planning and to set management goals [9]. A SCOR analysis of the level 1 processes described above indicates that plan, source, and deliver activities are the main drivers of efficient local food cold chains in Thailand [40].

3.4 Value chain

From an analysis of the value chain of golden apple snails, the main and supporting activities that add value to the final product are identified and shown in Tables 4-5. The chain of activities is carried out through five primary activities and four supporting activities according to the concept of the value chain as follows:

The five primary activities:

- For inbound logistics, factors affecting the quality of the golden apple snails should be managed. Good quality products can be achieved through the selection of natural raw material sources or standard breeding grounds.
- For operation, the activities should be planned. This includes a delivery strategy that can accurately and quickly move products to customers.
- For outbound logistics, there should be channels for contacting or collecting information among players in the chain. The appropriate mode of transportation is selected. The vehicles used are suitable for the quantity and type of goods. In addition, the on-time delivery of goods is also important.
- For marketing and sale, there should be a marketing strategy that aims to meet the target group for maximum satisfaction. In addition, there should be an introduction and explanation of food preservation methods that clearly show the advantages.
- For customer service, the focus should primarily be on the needs of consumers. Product delivery comes with an option of a refund if the perishable goods are not of good quality

The four supporting activities:

- For firm infrastructure, the establishment of integrated, easily accessible land transportation routes is suggested as the current routing comes from the expertise of the vehicle drivers themselves. Also, the collection of basic data for use in future analysis and forecasting is recommended.
- For human resource management, training in the fundamentals of packaging, storage, and transportation should be given to help minimise or eliminate product damage.
- For technology development, the procurement process should be developed along with product development. Perishable items should be developed to have extended storage times for freshness.
- For procurement, the raw materials should be purchased locally first. If that is not possible or sufficient raw material is not available, then materials can be obtained from neighbouring areas.

Table 4 Primary activities for the value chain of golden apple snails

Activities	Description
1. Inbound Logistics	To provide good quality products
2. Operation	To get the product according to the set goals
3. Outbound Logistics	To be able to distribute products evenly and thoroughly to customers
4. Marketing and Sales	To be able to maintain the old customer base and expand the new customer base
5. Service	To make the consumer aware of the product as much as possible

Table 5 Supporting activities for the value chain of golden apple snails

Activities	Description
1. Firm Infrastructure	To ensure efficient delivery of goods
2. HR Management	To create a link between stakeholders in the golden apple snail supply chain in terms of information flow and financial flow
3. Technology Development	To increase business efficiency
4. Procurement	To achieve a cost advantage

An analysis of the golden apple snail value chain described above suggests that improving procurement, enhancing inventory movement, and developing information management of demand and supply can help in delivering the aquatic product with minimal loss and waste. This result agrees with findings that optimising operations and management in cold chain logistics can improve the efficiency and sustainability of cold chain logistics for perishable food [5, 19].

4. Conclusion and suggestions

From the analyses conducted in this case study of the cold chain management, the SCOR model, and the value chain, the barriers and challenges to efficient and sustainable cold chain logistics for golden apple snails in Northeast Thailand can be summarised as follows:

1. Building an unbroken cold chain: This specific cold chain breaks during transport from the snail farmers to the storage/packaging facility. The warehouse that stores the goods does not practice proper storage methods. The transport that connects the links in the cold chain does not use proper refrigeration units. Thus, temperature fluctuations are found in the cold chain. Problems in any correlated and interdependent links in the cold chain will increase the loss and waste of food products. Therefore, guidelines that help reduce food loss towards building an unbroken cold chain includes

- Implementing appropriate precooling strategy at the upstream of the cold chain. Slurry ice cooling method that is suitable for most aquatic products can be used.
- Clearly identifying the duties of each employee for quick and effective solutions. Through coordinated development, operations and management could be optimised.

Information from each industry contributes to problem solving. Awareness of stakeholders in the cold chain is important to obtain correct and accurate information. The information can be transformed into digital data for efficient management. The stakeholders in the cold chain can use traceability to track the relationship between them or within the chain.

The potential benefits from maintaining cold chain logistics integrity offered to business practitioners may include an idea of the problems in the supply chain, a reduction of damaged/ spoiled food products and a support for customer share development.

2. Providing and maintaining appropriate temperature: Transport activity is one of the main issues affecting food loss. Long delivery periods and storage at improper temperatures with the use of ice coolers and tarpaulins can result in spoilage. The option of investing in temperature-controlled vehicles is suggested as they can provide consistent temperatures throughout the delivery period. Vehicle routing and scheduling in transportation support the reduction of food miles and greenhouse gas emissions. Therefore, recommendations for the improvement of the existing cold chain system include

- Creating partnerships among middlemen for mutual technology investment and knowledge sharing. This incurs extra expenses. Also, data sharing and transparency are essential.
- Insisting transport service providers undergo frequent inspection of goods. Relationship management with the service provider makes it possible in this context.

Developing a suitable temperature-controlled transport is an approach that minimises raw material or food product waste. Cost is the main reason for any business operator to decide on a choice of vehicle or cold storage facility.

Refrigerated transport may offer possible benefits to business practitioners through food quality conservation and reduction in costs related to food loss and waste.

3. Balancing supply and demand: The SCOR model indicates that a lack of demand forecasting and uncontrollable environments sometimes lead to snail shortages or oversupply. Also, excess supply results in a higher risk of product damage during storage. Therefore, an improvement in planning and sourcing decisions should be made. From the SCOR design, that is, modelling a value chain, it was suggested to improve procurement, enhance inventory movement, and develop information management of demand and supply. Therefore, recommendations for the improvement of the existing cold chain system include

- Operating in a contract farming way so that a sufficient number of snail farmers are available according to requirements. This is achievable as all parties involved are in the local area.
- Forming partners among entrepreneurs to meet the current demand for golden apple snails as well as possible consumption in the future due to expanding markets. However, information sharing is required to accomplish this goal. Also, the new market share has to be agreed upon by all partners.

The standard and process for enhancing food products or raw resources are determined by market demand. Guidelines for procurement and storage are established for each season based on research into market trends in the cold chain. The operating cost is reduced through accurate market trend analysis.

When the supply and demand are balanced, the potential benefits offered to business practitioners may include cost reduction, increase in net profit and increase in market share.

The results of this case study agree with findings that improving the efficiency and sustainability of cold chain logistics have implications for applying technology, improving equipment, and optimising operations and management in cold chain logistics [19]. This study provides guidelines to facilitate the planning of harvesting, storage, and transportation processes. The findings contribute to both operational and tactical decision making for business practitioners who need to reduce food loss and waste by building unbroken cold chains. The fisheries and fishing industry can also help to promote social awareness of efficient resource use and food loss measurement which can further create a sustainable national food future. Moreover, this study can be used as a reference for perishable food supply chains.

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