

## **CHAPTER 4 RESULTS AND DISCUSSION**

### **4.1 Mapping and the Cabbage Supply Chain Analysis**

#### **4.1.1 Cabbage Supply Chain Analysis in the Phetchabun Province and Royal Project Foundation, Chiang Mai, Thailand**

The traditional and good practice supply chains for cabbage produced in Phetchabun province and Royal Project Foundation, Chiang Mai, Thailand are as shown in Figure 4.1 and 4.2. Traditional chain is where the actors in the supply chain still use conventional methods at each point. The good practice chain is a good quality management system. The traditional cabbage supply chain involved four actors: growers and collectors in Phetchabun and nearby provinces, wholesalers in ‘Srimummuang’ wholesale market, Pathum Thani province and retailers in Bangkok (Figure 4.3). During harvesting season, the cabbage growers sold their harvested cabbage at provincial vegetable market located in Lomsak district, Phetchabun province every morning, about 30 km or 2 hours travel. After arrival at the provincial market, the cabbage were distributed and transported to Bangkok within 1 or 2 days, depending on the season. From provincial vegetable market in Phetchabun province to Bangkok is about 350 km or 6 hours travel with no cooling facilities during transportation. After arrival at wholesale market, the cabbages were distributed to retailers in the same market or nearby markets in Bangkok or others provinces (Kanchanaburi, Nakhon Pathom and Ratchaburi provinces). On the other hand, the good practice chain of cabbage under Royal Project Foundation, Chiang Mai, Thailand involved five main actors under the Royal Project Foundation (growers, packinghouse, central packinghouse, distributor, retailers). As in the good practice supply chain, growers delivered their cabbage to the Research Station Packinghouse over an average distance of 5 km and directly loaded to a precooling system at the station; the cabbages were then kept in a cold room at 2 °C overnight. Next morning, the cabbages were transported to a central packinghouse (Mae-Hia subdistrict), Chiang Mai province in the morning using a refrigerated truck (7 °C), which took about 2 hrs (80 km). After arrival at the central packinghouse, the cabbages were arranged for the distribution center and royal project shops in Chiang Mai and nearby provinces. The cabbage produced for distribution in Bangkok was transported in the late afternoon from Chiang Mai and arrived at a distribution center at Bangkok in the morning using refrigerated truck (5-7

°C), which took 9 hrs. At the distribution center, the cabbage was managed according to the schedule of the Royal Project shop and other customers within 2 days (Figure 4.4).



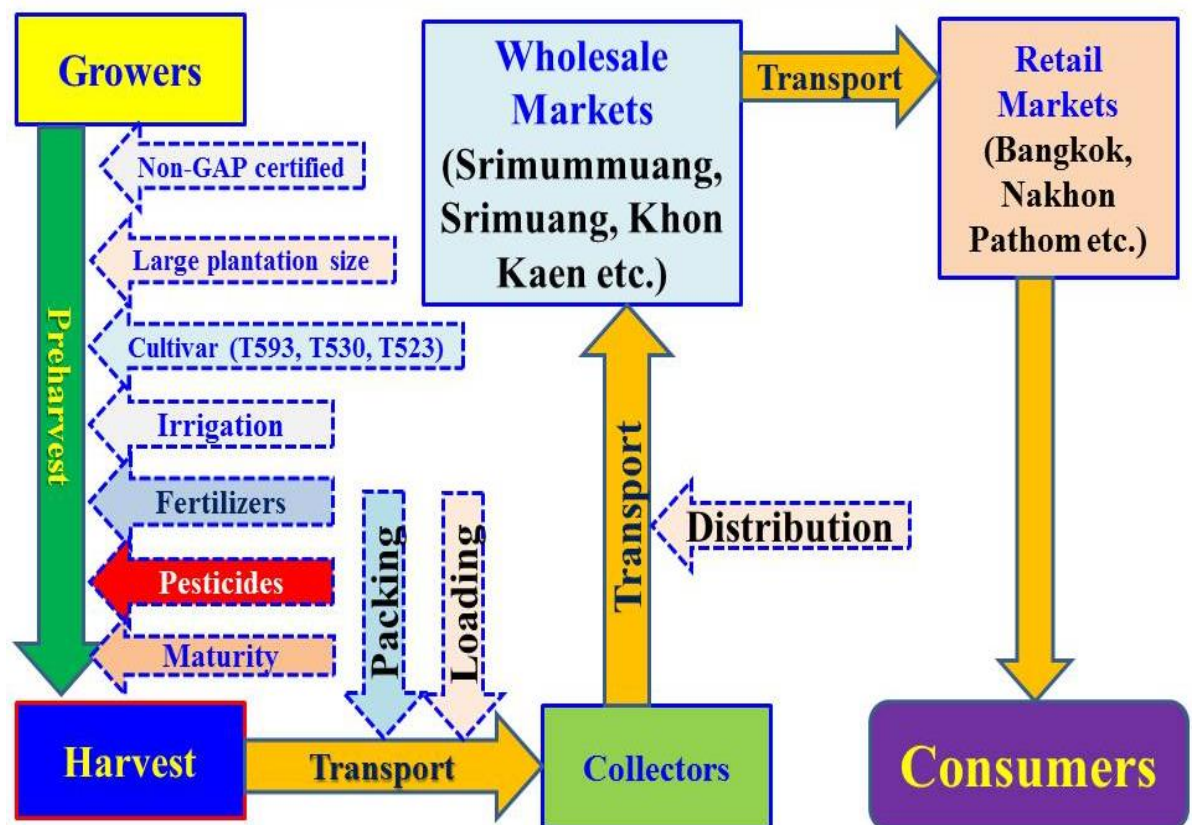
**Figure 4.1** Practices of cabbage supply chain in Phetchabun province (traditional chain), Thailand. (1=Seedbed preparation, 2=cabbage seedling, 3=transferring seedling to plantation area, 4=cabbage plantation area, 5=harvesting cabbage, 6=packing harvested cabbage, 7=transferring cabbage within the farm, 8=loading cabbage to the small truck, 9=transporting cabbage to collecting center, 10=delivering cabbage to collecting center, 11=selling cabbage at wholesale market and 12=selling cabbage at retail market).



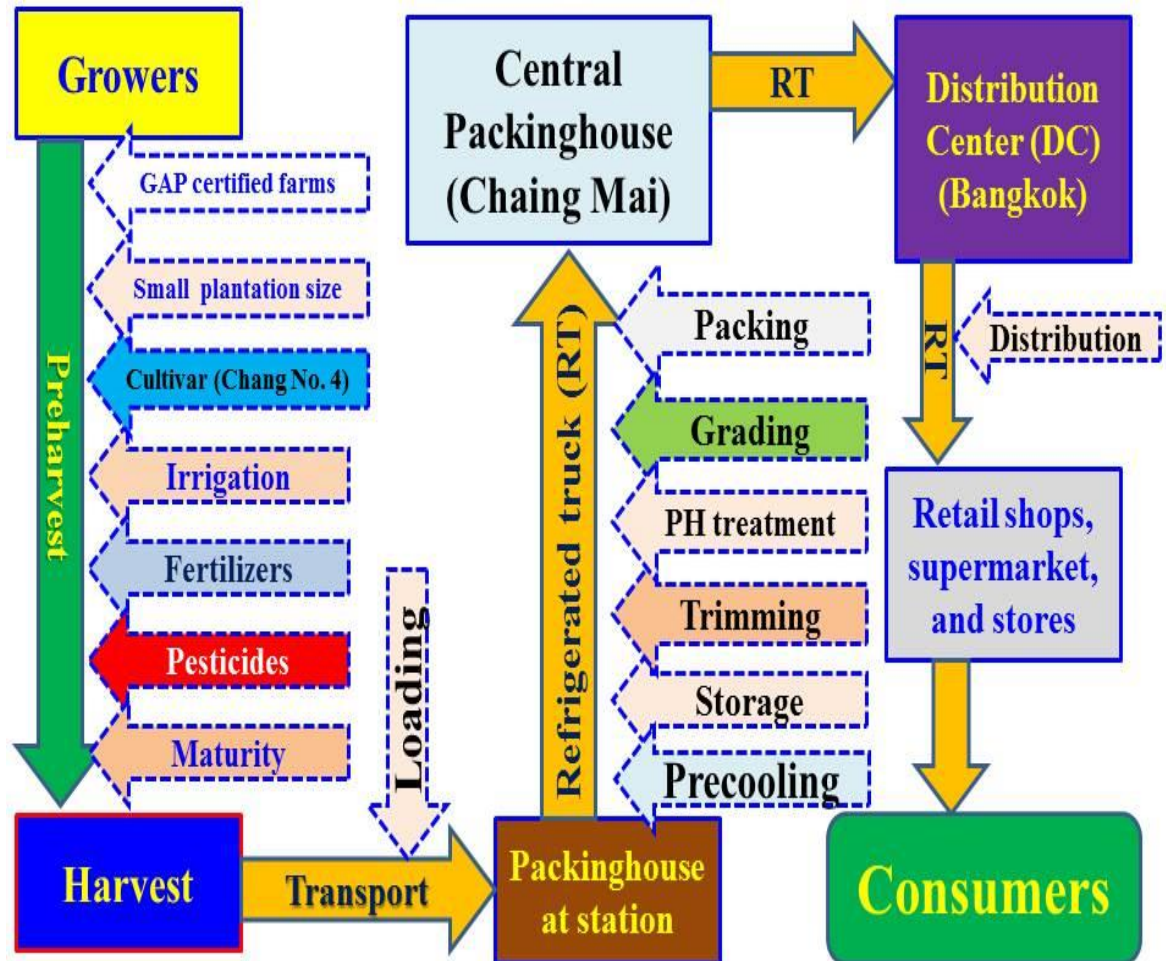
**Figure 4.2** Practices of cabbage supply chain in Royal Project Foundation, Chiang Mai province (good practice chain), Thailand. (1=seedbed preparation, 2=cabbage seedling, 3=transferring seedling to plantation area 4=cabbage plantation, 5=harvesting cabbage, 6=packaging for transport within the farm, 7=cabbage arrangement on the small truck, 8=loading at packinghouse, 9=trimming on the production line, 10=cabbage products, 11=distributing cabbage products using refrigerated truck, 12=cabbage available at supermarket).

#### 4.1.1.1 General Information of Cabbage Supply Chains

Supply chains for cabbage produced in Phetchabun province and the Royal Project Foundation for domestic consumption were mapped. Phetchabun and the Royal Project are located in the northern part of Thailand (Figure 3.1). Phetchabun is the highest producing province for cabbage in Thailand, accounting for the total harvested area of about 14,253 rai yielding 79,027 tons while in Chiang Mai province where the established the Royal Project, 13,179 rai yield 38,988 tons (Out of the Royal Project is also included) (DOAE, 2009).



**Figure 4.3** The cabbage supply chain in Phetchabun province (traditional chain).



**Figure 4.4** The cabbage supply chain in Royal Project Foundation (good practice chain).

#### 4.1.1.2 Demographic Information of Cabbage Supply Chain Actors

Growers in both traditional (Phetchabun) and good practice (Royal Project Foundation) supply chains were male-dominated and had an average farm size of 5.7 rai (Phetchabun) and 1.1 rai (Royal Project Foundation) and on average produced about 7.03 tons/rai for Phetchabun and 3.72 tons/rai for Royal Project Foundation (Table 4.1). Growers in the traditional and good practice chains were similar in ages, education (mostly no education), however growers in Phetchabun had more farming experience than those in the Royal Project chain. On the other hand, collectors, wholesalers and retailers in the traditional supply chain were female-dominated, had mostly finished primary school level and had been in the business for about 10.2-19.7 years. Collectors traded the biggest volume of produce while retailers traded the smallest as expected

because collectors dealt with a number of wholesalers before transporting produce from Phetchabun to Bangkok. In the good practice supply chain, the packinghouse was male-dominated since they performed the transportation to the central packinghouse. The packinghouse and distribution center consisted mostly of men that had less business experience but were higher educated (80% had finished secondary school level) than traditional supply chain actors in Phetchabun. The packinghouse at the research station consolidated the cabbages from growers under the Royal Project every day before transport to central packinghouse and distribution center in Bangkok, respectively; as a result, the traded volume was about 7.5 tons/day at the distribution center and 150 kg/day at the retail shop.

**Table 4.1** Demographic information of the Phetchabun province and Royal Project supply chain actors for cabbage in Thailand.

Supply chain actor	Gender (male:female)	Age, years	Education (%) <sup>*</sup>				Years in farming/business	Farm size, rai <sup>**</sup>	Yield/traded volume
			N	P	S	U			
<u>Phetchabun Province</u>									
Growers	96:4	39.7	66	32	2	-	13.5	5.7	7.0 tons/rai
Collectors	43:57	45.3	57.1	28.6	14.3	-	17.9	-	8.9 tons/day
Wholesalers	30:70	43.2	20	70	10	-	10.2	-	3.8 tons/day
Retailers	15:85	40.5	30	50	20	-	12.8	-	80 kg/day
<u>Royal Project</u>									
Growers	97.8:2.2	40.6	67.4	26.1	6.5	-	7.4	1.1	3.7 tons/rai
Packinghouses	60:40	52	-	-	80	20	10.0	-	7.5 tons/day
Distributors	67:33	44	-	-	50	50	8.0	-	7.5 tons/day
Retailers	5:95	38	-	-	58	42	5.0	-	150 kg/day

<sup>\*</sup>Education: P=primary school level or less, S=secondary school level and U=university level

<sup>\*\*</sup>Farm size (rai), 1 rai=0.16 hectare (ha)

### **4.1.1.3 Production Practices**

The grower is the first player in the cabbage supply chain. The production practices can be explained by the SCOR model as shown in Table 4.2.

#### **Plan**

In Phetchabun province, 22% of traditional growers had a plan to produce cabbage; the remaining 78% had no plan at all while the all growers under Royal Project had a plan to grow the cabbage (100%). The most important reasons for them were easiness to sell (60%), high income (60%) and experience of growers (50%) for traditional chain growers. For the growers under Royal Project, the contract farming system and support by the Royal (100%) were the main reasons for them to make a decision to grow the cabbage under the Royal Project. The GAP system was applied to all cabbage growers under the Royal Project Foundation in order to ensure all produce from the project was safe. On the other hand, most growers (78%) in the traditional chain still produced their cabbages using the traditional methodology. There was no contract farming system for cabbage growers in the traditional chain. However, cabbage is mostly grown from November and harvested in February (winter season) in both chains. This is because this season is the most suitable for growing cabbage. Additionally, cabbage cultivars were used in the traditional chain mainly bought from the Chia Tai seed company, Thailand. 'Chia Tai (T-530) and (T-593)' cultivars were mostly grown for growers in traditional chain in Phetchabun province, while the cabbage growers under Royal Project Foundation (100%) used Chang no. 4 cultivar for their farms because of their high yield, good quality, disease resistance and market demand. Most growers (52%) in Phetchabun province had cabbage production areas of 4-6 rai while only 16% had smaller planting area of 1-3 rai. A good number of growers (32%) cultivated cabbage in larger areas (>6 rai). Cabbage was produced usually three times a year. All cabbage growers in the Royal Project had a small farm size (1-3 rai). Additionally, they can take care or control their produce better than larger farm sizes, both in quality and quantity.

#### **Source**

Materials in the production processes included planting material, organic and inorganic fertilizers, pesticides, fungicides, herbicides and packaging. In Phetchabun, most traditional cabbage growers (68%) used seeds or seedlings from their own farm and another 32% of growers bought the seedlings from their neighbors, while 100% of

growers under Royal Project bought the seedling from the project. All the processes were managed by the project in order to control the quality of cabbage starting from seeds or seedlings. The knowledge of using fertilizers and pesticides of growers in Phetchabun province is mainly derived from their own experience and trading or exchanging with neighbors, while 100% of growers under the Royal Project came from an agricultural extension officer. They have a training or workshop for growers in order to produce good quality of cabbage. The growers in Phetchabun province bought fertilizers and pesticides mainly from a pesticides shop (100%), while the growers under the Royal Project bought their fertilizer and pesticides from the Royal Project (100%). Additionally, after harvesting, the packaging is important for handling the produce. In Phetchabun, all growers used perforated bags for packing their cabbage before delivery to the collectors while the growers under the Royal Project used plastic bamboo baskets (74%) and plastic crates (26%).

## **Make**

Production practices and situations existed between growers in Phetchabun and those in the Royal Project supply chains. Growers in the Phetchabun chain seemed to be more stable and technologically more updated since all of them owned the land they till and less of them knew and practiced Good Agricultural Practices (GAP) than growers in the Royal Project chain. The soil in Phetchabun devoted to cabbage production was fertile, being organic in the mountain area as well as soil type in production areas of growers under the Royal Project Foundation, where loamy sandy is the major soil type. Prior to field planting, which is usually between April to June in order to harvest in July to October, seedlings were raised following the seedbed method. Seed requirements were higher for Phetchabun chain growers as they had larger production area than the Royal Project chain growers. Most growers transplanted the seedlings when they about 30 days old and the seedlings were spaced at 30×30 cm for Phetchabun (78%) and 50×50 cm for growers under Royal Project Foundation (82.6%). Most farms in the Phetchabun chain were only cleared of weeds after which the seedlings were directly planted (68%), while the growers under the good practice chain plowed and harrowed the field before planting (78.3%) (Table 4.2). Cultivation practices of cabbage included fertilizer application, irrigation, weed control and insecticide spray. No grower in both chains applied fungicide for disease control, also reported by Chanthasombath (2011).

Knowledge on fertilization and insect pest control was mostly based on experience and/or exchange of knowledge with neighbors as well as pesticide shops for the Phetchabun chain. Most of the growers under the Royal Project Foundation got the knowledge from the training program of the Royal Project as well as the agricultural extension officer. Additionally, for growers in the traditional chain, traders were the most mentioned source of knowledge on fertilizer application. Almost all growers in both chains applied inorganic fertilizer before and after planting, usually using ammonium phosphate (16-20-0), and in a few cases, N-P-K at a ratio of 16-20-0 or 15-15-15 and/or urea (46-0-0) were applied. Most growers in the Phetchabun chain applied organic fertilizer (chicken manure) in combination with inorganic materials, with more growers in the traditional chain applying it before field planting than growers in the Royal Project chain. The rate of inorganic and organic fertilizer application did not vary greatly among growers in both chains. Similarly, growers in both chains employed basal application of fertilizer before planting and side-dressing after planting. The cost of inorganic fertilizer was the same for growers in both chains while the cost of organic fertilizer was slightly higher for the traditional chain. Cabbage production in both chains was mostly rainfed (>70%). Growers in both chains also used river water to irrigate their farms with the aid of a water pump. The irrigation cost was almost the same in both chains. Weed control was usually done by manual weeding, especially for the Royal Project chain growers; very few used machine or applied herbicide (37% and 13%). Growers in traditional chains had higher cost for weed control because they applied herbicides to control weeds in the field. For insect pest control, the use of pesticide was widespread, especially in the traditional chain, resulting in higher cost of weed control than that of the good practice chain. Based on these results, it appears that the Royal Project chain growers were more knowledgeable in growing cabbage, and were more judicious in applying insecticides than traditional chain growers. However, growers in both chains heavily used inorganic fertilizers, which could have future detrimental effects on soil quality if no remedial measure is applied, such as the use of organic fertilizer. Furthermore, the production practices documented are a strong basis for the production systems of growers in both chains. Most growers (>90%) in both Phetchabun and the Royal Project chain used a combination of firmness testing and counting days after planting in order to harvest at the commercial maturity stage. After harvesting, the 10 kg of harvested cabbage with wrapper leaves (5-6 leaves) were packed into perforated bags in the Phetchabun chain while in the Royal Project chain,

the harvested cabbage was transferred to a small truck using a bamboo basket or plastic crate.

### **Delivery and return**

In the Phetchabun chain, growers delivered their produce to the collectors at the collecting center in the market with a distance ranging from 30-40 km. Despite the long distance, damage to the produce was not significant since cabbage heads had several wrapper leaves for protection. Normally the collectors bought all the produce from the growers. No grade standard was used and only insect and disease damage was of concern to the collectors. For the Royal Project chain, after harvesting cabbage was delivered to the packinghouse at the research station of a distance ranging from 5-10 km. At the packinghouse, the officers checked the external quality and removed some wrapper leaves. The cabbage was not returned during the period of study. As we asked from the officer, it was a very rare case to return the cabbage to the grower because before harvesting they have to ensure that pesticide residue in cabbage is safe for consumers by primary checking before harvesting.

Table 4.2 Comparison of the management of growers in the cabbage supply chain based on the SCOR model.

SCOR Item/Descriptor	Frequency (%)* or as specified	
	Phetchabun	Royal Project
<b>1. Planning</b>		
Plan for growing cabbage		
-No	78	-
-Yes	22	100
Reason/s for growing cabbage		
-Easy to sell	60	54.3
-Experience of grower	50	86.9
-High income	60	82.6
-Under contract farming	10	100
-Project supported production	-	100
Farm size		
-small (1-3 rai)	16	100
-medium (4-6 rai)	52	-
-large (>6 rai)	32	-
Cabbage cultivars used		
-Chang no. 4	2	100
-Chia Tai (T523)	11	-
-Chia Tai (T530)	46	-
-Chia Tai (T593)	41	-
Reason for using the cultivar		
-High yield	94	97.8
-Good quality	86	91.3
-Market/buyer need	94	86.9
-Disease resistance	82	97.8

**Table 4.2 (Cont.)**

SCOR Item/Descriptor	Frequency (%)* or as specified	
	Phetchabun	Royal Project
GAP System		
-none	78	-
-GAP certified	22	100
Contact farming system		
-none	100	-
-signed contract	-	100
<b>2. Sourcing</b>		
Plant materials (seedling/seed)		
-prepared by their own farm	68	-
-bought	32	100
Source of knowledge for fertilizer/Pesticides application		
-Based on experience	76	65.2
-Agricultural extension officer	24	100
-Trader	64	21.7
-Exchange with neighbor farmers	72	58.7
Fertilizer/Pesticides		
-Pesticide shops	100	-
-Cooperative stores	-	100
Type of packaging used in the farm		
-Bamboo basket	-	74
-Plastic bag	100	-
-Plastic crate	-	26
<b>3. Making</b>		
Land preparation		
-Clearing and direct planting	68	21.7
-Plowing and harrowing	32	78.3

**Table 4.2 (Cont.)**

SCOR Item/Descriptor	Frequency (%)* or as specified	
	Phetchabun	Royal Project
Spacing between plants		
-50 × 50 cm	22	82.6
Type of fertilizer		
<u>Inorganic</u>	100	100
-Before planting (all 16-20-0), %	15	8.7
-After planting (days from planting)		
-16-20-0	70	85
-15-15-15, 46-0-0	85	91.3
<u>Organic (chicken manure)</u>		
-Before planting	100	78.3
-After planting	72	65.2
Rate of fertilizer application, kg/rai		
<u>Inorganic</u>		
-Before planting	-	-
-After planting	200	150
<u>Organic (chicken manure)</u>		
-Before planting	300	250
-After planting	100	100
Irrigation system		
-Rainfed	70	73.9
-Use water pump from river	30	26.1
Weed control		
-Physical method	48	87
-Manual weeding	48	50
-Machine	-	37
-Chemical method (herbicide spraying)	52	13

**Table 4.2 (Cont.)**

SCOR Item/Descriptor	Frequency (%)* or as specified	
	Phetchabun	Royal Project
Insecticide used		
<u>Source of knowledge</u>		
-Based on experience	60	89.1
-Agricultural extension officer	70	100
-Trader	86	67.4
-Knowledge exchange with neighbor growers	86	67.6
<u>Name of insecticide</u>		
- <i>Bacillus thuringiensis</i>	60	100
-Abamectin (1.8% EC)	86	34.8
-Permethrin (25%EC)	32	21.7
-Carbaryl (85% WP)	22	10.9
<u>Amount of insecticide/cropping</u>		
-<100 cc	-	100
->100 cc to 2,500 cc	78	-
-Method of application (spraying)	88	100
Harvesting maturity index		
-Firmness testing (a)	2	-
-Days from planting (b)	8	-
-Combination of above (a)+(b)	90	100
<b>4. Delivery</b>		
Distance from farm to collecting center/packinghouse		
-≤10 km	100	-
->10 km	-	100
<b>5. Return</b>		
-None	100	100
-Return to grower	-	-

#### **4.1.1.4 Harvesting and Postharvest Practices**

##### **4.1.1.4.1 Harvesting Management**

Table 4.3 summarizes the harvesting and postharvest practice for cabbage in the traditional and good practice chains. The growers harvested the cabbages based on head firmness, number of days elapsed from planting, or their combination (90-100%). The harvested cabbages were packed into plastic bag with holes. The outer leaves (5-6 leaves) of cabbage still remained in order to protect from damage during transport. When mature, cabbages were not harvested right away; instead, the majority of the growers waited for 3-4 days before harvesting was done. Delaying harvest could lead to head cracking, which is a typical symptom of over-maturity, with loss of quality as a consequence. A significant number of growers (60%) in the traditional supply chain harvested the cabbages after a certain period then sold to a collector at a collecting center. This would not cause maturity problems, but the price is based on the amount and consumer demand, while the good practice chain managed the harvesting time by packinghouse at the research station under the Royal Project Foundation based on ordering. Harvesting was usually done by cutting the base of the cabbage head using an ordinary sharp knife then trimming some leaves off (remaining 3-4 leaves).

##### **4.1.1.4.2 Postharvest Practices**

Postharvest practices of cabbage including trimming, sorting, packaging, storage and transporting were the usual operations after harvesting, and the postharvest practices differed between each supply chain. In the traditional supply chain, growers delivered the cabbages packed in plastic bags with holes (10 kg) or unpacked to the collector at a collecting center in the provincial market using a small car (pick-up). There was no trimming at the collecting market (Figure 4.4). In the good practice chain, the harvested cabbages were then placed in a container (plastic crate) or on a layer of cabbage (head by head) in the truck, and then transported to a packinghouse at a research station (Figure 4.5). At the packinghouse, the officer checked external quality and removed the outer wrapper leaves (remaining 3 wrapper leaves), then put all cabbage into a precooling system in order to reduce field heat. The cabbage was then stored in a cold room overnight (2-4 °C). There was no special postharvest treatment, just keeping the cabbage at low temperature during storage or transporting to a central packinghouse or distribution center.

**Table 4.3** Harvesting practices of growers in the Phetchabun province and Royal Project chains (frequency, %).

<b>Harvesting practice</b>	<b>Phetchabun chain</b>	<b>Royal Project chain</b>
<b>Harvest maturity index</b>		
Firmness	2	0
Days from planting	8	0
Combination of above	90	100
<b>Time to harvest when mature</b>		
Immediately	10	8.7
After a certain period	60	13.0
Based on collector order/packinghouse	30	78.3
<b>Method of harvesting</b>		
Sharp knife used to cut the base of cabbage	100	100

**Table 4.4** Postharvest practices of the Phetchabun province supply chain actors (frequency, %)\* and description of practice.

<b>Practice</b>	<b>Growers</b>	<b>Collectors</b>	<b>Wholesalers</b>	<b>Retailers</b>
Trimming	35	0	30	100
	removed damaged outer leaves	-	removed damaged outer leaves	removed outer leaves
Sorting/grading	80	0	0	0
	free of insect pest and damage	-	-	-
Packaging	100	100	100	0
	plastic bag (10 kg/bag)	plastic bag (10 kg/bag)	plastic bag (10 kg/bag)	-
Storage	14	100	100	70
	kept under shade	under shade with ambient conditions	ambient conditions	kept under shade
Transporting	100	71.4	100	100
	small truck (pick-up)	small truck, other (28.6%)	small truck (pick-up)	small truck (pick-up)

\*multiple responses

**Table 4.5** Postharvest practices of the Royal Project supply chain actors (frequency, %) and description of practice.

Practice	Growers	Packinghouse	Distributor	Retailers
Trimming	100	100	50	30
	removed some outer leaves	removed some outer leaves	removed some outer leaves	removed some outer leaves
Sorting/grading	0	100	0	0
	-	size and weight	-	-
Special treatments	0	100	100	0
	-	sodium hypochlorite (150 ppm)	sodium hypochlorite (150 ppm)	-
Packaging	65	100	100	100
	bamboo baskets or plastic crates (35%)	plastic crates	plastic crates	plastic bag (PE with holes)
Storage	35	100	100	100
	kept under shade	cold storage (2-5 °C)	cold storage (4-7 °C)	control temperature (7-8 °C)
Transporting	100	100	100	100
	small truck	refrigerated truck	refrigerated truck	mini refrigerated truck

#### 4.1.1.5 Postharvest loss

According to the collecting data from cabbage supply chain actors, growers incurred a loss of 15% in the traditional supply chain, while in the good practice supply chain, only 8% postharvest loss was observed (Table 4.6). Main causes were insect damage during the preharvest period and mechanical damage during postharvest handling. The major losses occurred during transport from collector to retailer, and losses differed with each supply chain actor. In the traditional chain, collectors incurred about 6% of the losses due to physical damage as a result of careless handling during prepacking and loading operations. Similarly, wholesalers incurred much higher loss of 10% as a result of more physical damage that usually developed on the sensitive tissue of the damaged parts of cabbages. Additionally, warm and moist conditions inside the plastic bags during the 6 hours journey from Phetchabun to Bangkok probably provided conditions to increase damage development. At the retailers' level, loss was 6% due to weight loss and

trimming of wilted outer leaves. In total, cabbage losses from growers to retailers were about 37%.

In the good practice chain, growers had a loss of 8% due to insect damage. This was the most important issue for cabbage growers to protect their cabbage in the field. The loss incurred by packinghouse was about 3%; this was realized on arrival at central packinghouse under the Royal Project Foundation, and there were additional 5% and 3% losses at the distribution center and retailer, respectively. The major causes were physical damage. In total, the good practice chain had a loss of 19%.

Earlier, it was reported that postharvest loss estimates in developing countries ranged from 20-50% of production, varying with commodity, location and growing season (Kader and Rolle, 2004). In Thailand, outright volume losses of red cabbage were estimated at an average of 14-19% (Boonyakiat, 1999). The results of present study showed a higher loss situation existed in both traditional and good practice chains compared to previous studies. It is worth noting that losses in the traditional chains were much higher than that in the domestic chain due to cultivation practices and postharvest handling system. This was observed to be due to more trimmings of outer damaged parts of cabbages performed by wholesalers and retailers who had more stringent quality requirements.

**Table 4.6** Postharvest loss of cabbage in the Phetchabun province and Royal Project supply chains in Thailand.

<b>Supply chain actor</b>	<b>Postharvest loss (%)</b>	<b>Major causes of loss</b>	<b>Price of cabbage (Baht/kg)</b>
<b><u>Phetchabun Province</u></b>			
Growers	15	Insect damage	3.5
Collectors	6	Physical damage and wilting	5.0
Wholesalers	10	Physical damage and wilting	7.0
Retailers	6	Physical damage and wilting	15.0
Total loss	37		
<b><u>Royal Project</u></b>			
Growers	8	Insect damage	5.4
Packinghouse	3	Physical damage and wilting	10.0
Distributors	5	Physical damage and wilting	15.0
Retailers	3	Wilting and soft rot	35.0
Total loss	19		

## **4.1.2 Quantifying Postharvest Losses of Cabbage in the Supply Chain in Phetchabun Province, Thailand**

### **4.1.2.1 Cause of Postharvest Loss of Cabbage in the Supply Chain**

The causes of postharvest loss of cabbage in our previous survey in 2010 are described in Table 4.7. The postharvest handling of cabbage in the study area still involved traditional techniques without concern for contamination and food safety standards. Moreover, the transport and distribution systems of cabbages from farm to collecting center used a small truck (pick-up). However, there was a serious problem in the infrastructure from farms in the highlands to flat areas. At the collecting center, there were no cooling facilities to keep the quality of cabbages before selling to the wholesalers. Occasionally, cabbages were in processes for 2 or 3 days without a cooling system at the collecting center. The packaging for cabbages only consisted of polyethylene (PE) bags with holes. Cabbages were packed to about 10 kg per bag. In general, when the cabbages reached a wholesale market, some of the cabbages were distributed to retailers at the retail market and some of the cabbages were trimmed by

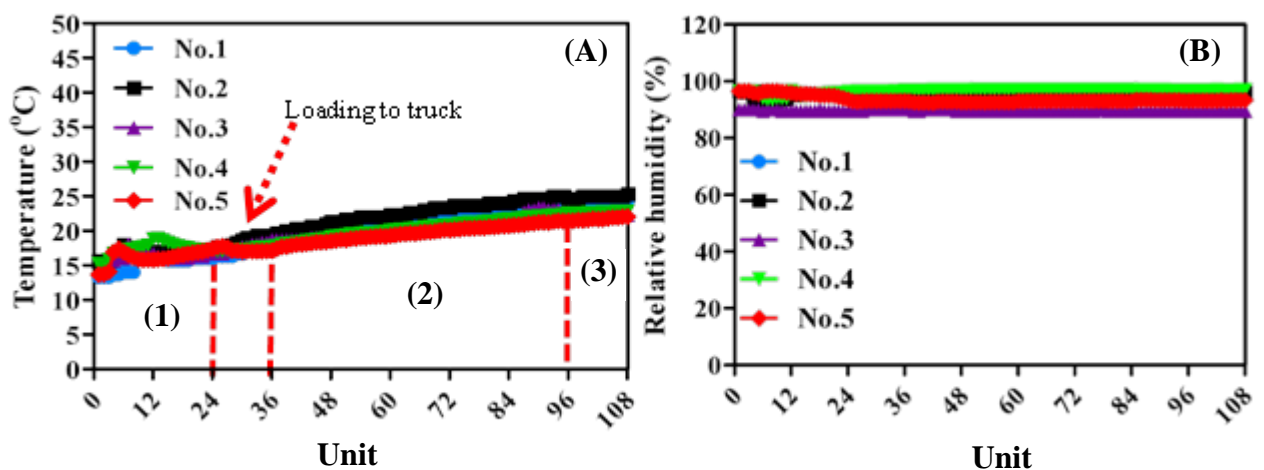
wholesalers for consumers. In addition, there were a lot of damaged cabbage leaves at wholesale markets. Finally, the trimmed leaves were transported to farms for animal feed.

**Table 4.7** Generic examples of cabbage loss in the supply chain.

<b>Stage</b>	<b>Examples of cabbage loss characteristics</b>
(1) Harvesting handling	Poor handling techniques, crops damaged during harvest, edible cabbages left in the field
(2) Transport and distribution	Transport infrastructure, loss owing to spoiling/bruising
(3) Storage	Pests, disease, spoilage, contamination
(4) Processing (trimming)	Contamination in the process causing loss of quality
(5) Packaging	Inappropriate packaging causing damage to produce
(6) Marketing, selling and distribution	Damage during transport: spoilage and poor handling in wet market losses caused by lack of cooling/cold storage
(7) End of life disposal of cabbage loss at different stages of the supply chain	Discarded food loss separately treated, fed to livestock/poultry, mixed with other waste and landfilled

#### 4.1.2.2 Temperature and moisture content of cabbage during transportation

The temperature and humidity data in the cores of cabbage bags during transport were recorded. The results showed that the temperature inside the cabbage bags at the farm was about 13 °C with 96% relative humidity (RH) (Figure 4.5). After that, the small truck took only 2 hours from the farm to the collecting center in the provincial market. The temperature was gradually increased to 15 °C and 96% RH. During transport of the cabbages to the wholesale market, the temperature was about 17-23 °C, while the temperature of cabbage bags at the retail market was about 25 °C. However, the percent of RH was relatively constant during transport from the farm to the retail market (96-98% RH) as shown in Figure 4.5A.

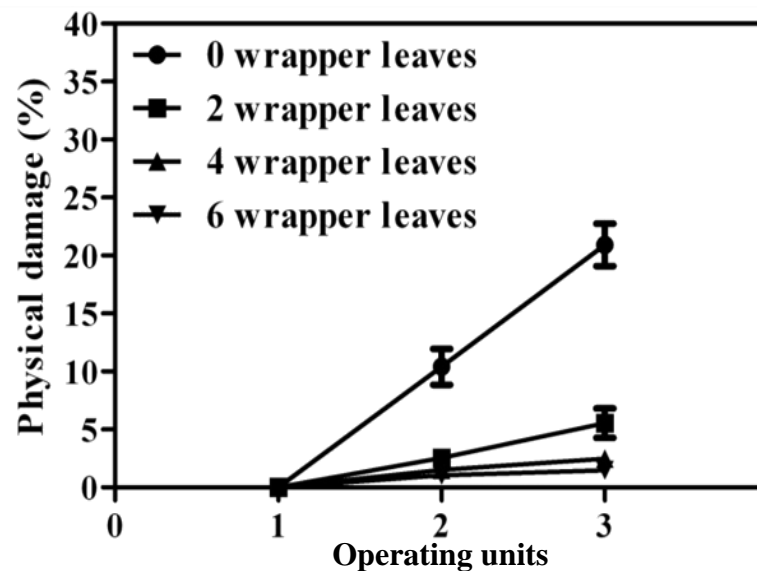


**Figure 4.5** Temperature (A) and relative humidity (B) of cabbages during transport from farms in Phetchabun province (1) to wholesale (2) and retail market (3) in Bangkok, Thailand. (One unit of data was collected at every 5 minutes interval)

#### 4.1.2.3 Quantifying postharvest loss of cabbage in supply chain

After harvest, some growers removed various numbers of cabbage wrapper leaves before packing into plastic bags while some growers kept several wrappers in order to increase cabbage weight to increase their income. It should be noted that several wrapper leaves are transported with only a small edible portion, which increases the cost of transport to the market. However, if growers removed all wrapper leaves before transport the result was more severe problems of physical damage during transport (about 22-25% loss at the retail market) (Figure 4.6). Most of the physical damage to

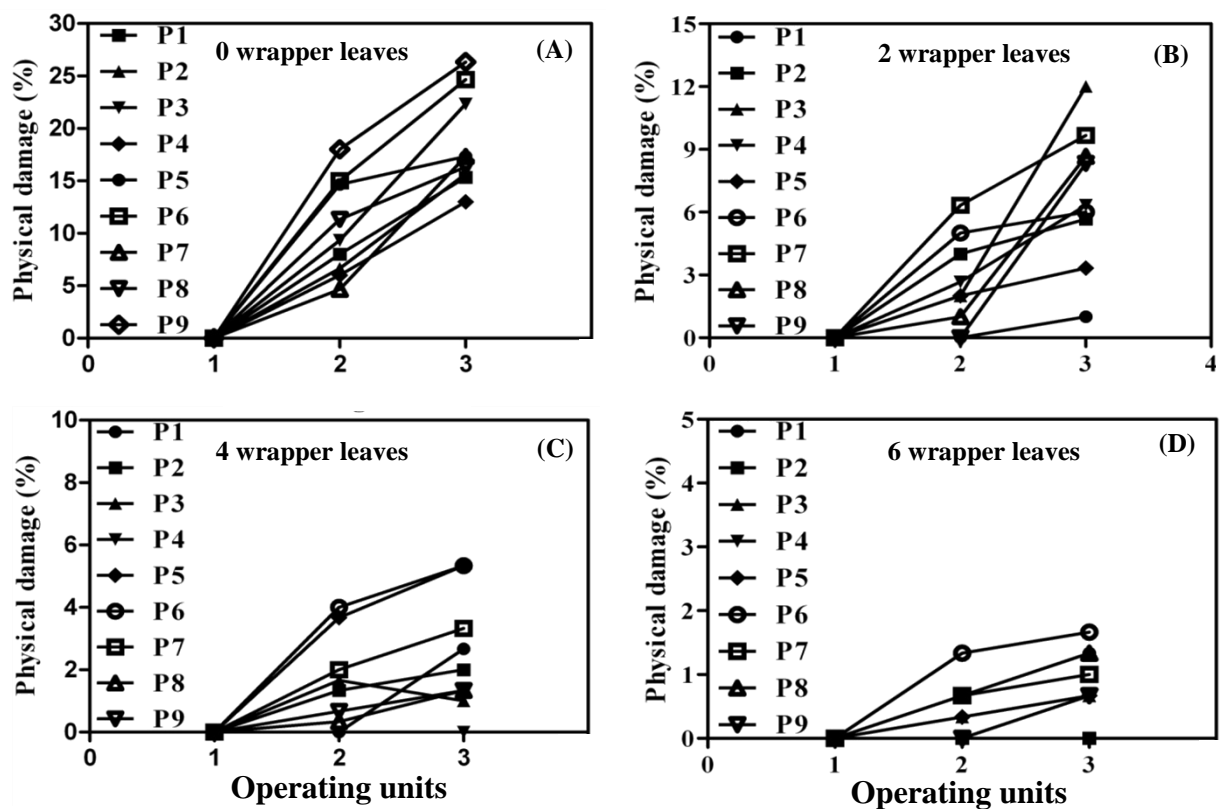
fruits and vegetables results from vibrations and impacts (Singh and Singh, 1992). These vibrations and impacts are caused from the irregularities of the road surfaces and are transmitted from the suspension systems of the vehicles to the produce. On the other hand, the cabbages with at least 2 wrapper leaves had better protection during transportation. The postharvest loss from physical damage of cabbage head with 2 wrapper leaves was about 6%. In addition, there were only 3 and 2% losses in cabbages with 4 and 6 wrapper leaves, respectively.



**Figure 4.6** Severity of physical damage of cabbages with different numbers of wrapper leaves during transportation from farms in Phetchabun Province (1), to wholesale market (2) and retail markets (3) in Bangkok, Thailand.

The postharvest loss of cabbage due to physical damage during transportation was estimated. The cabbage bags were positioned on the truck with 9 different locations (Figure 3.3). The results showed that cabbages positioned on the top layer of the truck (P3, P6 and P9) had the most severe physical damage (Figure 4.7A and B). The physical damage percentages of cabbages without wrapper leaves were about 22, 24 and 25% in P3, P6 and P9 at retail market, respectively. The cabbages at the bottom layer (P1, P4 and P7) had less physical damage than other layers of about 14, 12 and 15%, respectively (Figure 4A). However, cabbages with 4 or 6 wrapper leaves had less physical damage loss, about 5% and 1.5% at the bottom layer of the truck (P1) (Figure 4.7C and D). Losses directly attributed to transporting can be high, particularly in

developing countries (Kader, 2005). Moreover, damage occurs as a result of careless handling of packed produce during loading and unloading, vibration (shaking) of the vehicle, especially on bad roads, and poor stowage, with packages often squeezed into the vehicle in order to maximize revenue for the transporters (FAO, 1989). Overheating leads to decay and increases the rate of water loss. This can happen in transport as a result from using closed vehicles with no ventilation, stacking patterns that block the movement of air, and using vehicles that provide no protection from the sun (Dixie, 2005). Moreover, vehicle breakdowns can be a significant cause of losses in some countries, as perishable produce can be left exposed to the sun for a day or more while repairs are carried out (World Resources Institute, 1998).



**Figure 4.7** Physical damage of cabbages with different numbers of wrapper leaves (0 wrapper leaves [A], 2 wrapper leaves [B], 4 wrapper leaves [C] and 6 wrapper leaves [D]) and positioning on the truck during transport from farms in Phetchabun Province (1), wholesale (2) and retail markets in Bangkok, Thailand. (P1 to P9 are described in Figure 3.3)

### 4.1.3 Cost and Return on Investment (ROI) in the Cabbage Supply Chains

Product quality and quantity losses contributed to price disparity along the chain. In the traditional supply chain, the farmgate price (3.5 Baht/kg) was 1.5 Baht/kg lower than that of collectors (5 Baht/kg) and two times lower than that of the wholesaler (7.0 Baht/kg) (Table 4.8 and 4.9). The value-adding activities contributing to the collectors' price included transportation. Additionally, the retail prices offered to consumers were 15 Baht/kg. In the good practice supply chain, growers earned about 5.4 Baht/kg higher than that in the traditional supply chain since the price was for whole cabbages with wrapper leaves intact (i.e. untrimmed heads); this is nearly double that of the traditional supply chain. Some growers also revealed that the modern market provides more assurance of high-volume orders and price guarantee. The packinghouse selling price was about 10 Baht/kg, which is almost two times higher than at the farmgate price, while the selling price of distribution center and retail shop was much higher, about 15 and 35 Baht/kg, respectively, due to the costs of postharvest operation (e.g. trimming, packaging and packing) and transportation.

Growers in both chains had different costs of production. The growers in the traditional chain had higher cost of production of almost 4,000 Baht/rai; the main expense came from fertilizers. The growers did not incur postharvest handling costs (trimming, sorting), as they just brought the harvested cabbages intact and packed them in plastic bags with holes (10 kg/bag), sold them to the collector at provincial vegetable market where they were direct loaded to the latter's truck (Table 4.8), while the good practice chain grower brought their cabbage to the packinghouse. However, the higher yields in the traditional chain gave the growers had higher net income, while lower net income and return on investment (ROI) were observed in the good practice chain growers. ROI for traditional and good practice chain growers was high, 89.2% and 96.0%, respectively. Collectors had the highest net income among traditional chain actors due to the low handling cost and wide price margin between their buying price offered to growers and selling price offered to wholesalers, while ROI had almost the same among the supply chain actors (Table 4.9). Collectors, wholesalers and retailers had ROI of 22.3, 22.1 and 20% respectively. Daily net income of wholesalers and retailers represented only the income from one commodity; they are trading more vegetables other than cabbage.

As seen previously, asymmetry in economic opportunities was very evident in both traditional and good practice supply chains, with the growers who were all smallholders receiving the least as shown by the great disparity in farmgate, wholesale and retail prices and accordingly, ROI. Strategies to expand the economic opportunities of small growers usually entail collective mechanisms to gain economies of scale, do value addition activities, and engage directly with markets (Shepherd, 2007). If properly managed, such collective action could enable participation of small growers in coordinated supply chains, which are principal commercial tools for competitive strategies (e.g. labeling, branding), assuring quality and better logistics, and expanding market and income opportunities (Van der Meer, 2006).

**Table 4.8** Cost and return analysis (Baht/rai/growing season) for growers in the Phetchabun province and the Royal Project supply chains.

Harvesting practice	Phetchabun Province	Royal Project
<b>A. Gross income (A4)×(A5), Baht/rai</b>	24,605	18,480.96
A.1 Yield in kg/rai	7,030.0	3,720.0
A.2 Loss (%)	15	8
A.3 Loss of volume, kg/rai	1,054.5	297.6
A.4 Salable volume, kg/rai	5,975.5	3,422.4
A.5 Price/kg, Baht	3.5	5.4
<b>B. Cost (B.1+...+B.10), Baht/rai</b>	13,002.5	9,430.6
B.1 Seeds	1,275	850
B.2 Land preparation	1,600	1,200
B.3 Fertilizers	5,880	4,410
B.4 Irrigation	900	1,050
B.5 Weed control	600	480
B.6 Insecticide	1050	550
B.7 Packaging cost	490	280
B.8 Harvesting cost (labor)	650	350
B.9 Postharvest handling cost (labor)	200	200
B.10 Fuel for transport**	357.48	59.58
<b>C. Net income (A-B), Baht/rai</b>	11,602.5	9,050.4
<b>D. Return on investment (ROI), (C/B)</b>		
× 100 (%)	89.2	96.0

\*Postharvest handling cost not provided as growers directly brought the harvested cabbages to collectors.

\*\*Price of fuel (diesel) on 27 November, 2010 from Bangchak Petroleum Company Limited, 1 liter=29.79 Baht,(Collection center at Lomsak district [Phetchabun] to 'Srimummuang' Wholesale Market [Bangkok] ≈ 346 km)

**Table 4.9** Cost and return analysis (Baht/day) for collectors, wholesalers and retailers in the Phetchabun Province supply chain.

Item	Collector	Wholesaler	Retailer
<b>A. Gross income (A.4) × (A.5), Baht/day</b>	41,830	23,940	1,128
A.1 Traded volume/day, kg	8,900	3,800	80
A.2 % Loss	6	10	6
A.3 Loss volume, kg	534	380	4.8
A.4 Salable volume, kg	8366	3,420	75.2
A.5 Selling price, Baht	5	7	15
<b>B. Cost (B.1+...+B7), Baht/day</b>	34,200	19,600	940
B.1 Cabbage (A.1) × (buying price)	31,150	19,000	640
B.2 Rental property cost	150	200	50
B.3 Trimming cost	0	0	0
B.4 Sorting cost	0	0	0
B.5 Packaging cost	0	0	0
B.6 Fuel/Transport cost*	2,500	0	150
B.7 Labor cost	400	400	100
<b>C. Net income (A-B), Baht/day</b>	7,630	4,340	188
<b>D. ROI, (C/B) ×100 (%)</b>	22.3	22.1	20

\*Price of fuel (diesel) on 27 November, 2010 from Bangchak Petroleum Company Limited, 1 liter=29.79 Baht

In the good practice chain, the distributor had much higher daily net income than the packinghouse and retailers (Table 4.10). On other hand, the retailer had lowest net income due to the amount of traded volume within a day. Additionally, ROI of retailers was highest among chain actors. This was due to the selling price of cabbage at retail shops or market being higher than with chain actors.

**Table 4.10** Cost and return analysis (Baht/trip) for packinghouses, distributors and retailers in the Royal Project supply chain.

Item	Packinghouse	Distributor	Retailer
<b>A. Gross income (A.4) × (A.5), Baht/trip</b>	48,500	106,875	5,092.5
A.1 Traded volume/trip, kg	5,000	7,500	150
A.2 % Loss	3	5	3
A.3 Loss of volume, kg	150	375	4.5
A.4 Salable volume, kg	4,850	7,125	145.5
A.5 Selling price, Baht	10	15	35
<b>B. Cost (B.1+...+B.4), Baht/trip</b>	31,783.5	76,750	2,897.9
B.1 Cabbage (A.1 × buying price)	25,000	75,000	2,250
B.2 Trimming cost	600	1,250	200
B.3 Packaging cost	1,000	1,500	150
B.4 Transport cost (fuel, labor)*	5,183.5	500	297.9
<b>C. Net income (A-B), Baht/trip</b>	16,716.5	30,125	2,194.6
<b>D. ROI, (C/B)100, %</b>	52.6	39.3	75.7

\*Price of fuel (diesel) on 27 November, 2010 from Bangchak Petroleum Company Limited, 1 liter=29.79 Baht (Royal Project Packinghouse [Chiang Mai] to distribution center [Bangkok] ≈ 696 km)

## **4.1.4 Improvement of the Cabbage Supply Chain in Phetchabun Province**

### **4.1.4.1 Sample Characteristics**

The major growers in this area are hill tribes and farming is the major economic activity for supporting their families. Some growers have changed their farming techniques from conventional farming to more environmentally sustainable and high-yielding farming practices in accordance to consumers' preferences. The growers who followed GAP are highly experienced in farming technologies. All of them have over ten years of practical experience in cabbage cultivation (Table 4.11). Most growers who followed GAP are still young, educated and interested to participate in cabbage cultivation. There were some growers with GAP certification that succeeded in directly contacting the wholesalers in different provinces (57.1% of all GAP certified farms). In addition, all GAP certified farms made a plan before growing each season (Table 4.11).

### **4.1.4.2 Cabbage Supply Chain in Phetchabun Province**

The cabbage supply chain in Phetchabun province was mapped, as shown in Figure 4.8. It was to note that the existing cabbage supply chain may be comprised of several channels as well. The major stakeholders of the cabbage supply chain include growers, collectors, wholesalers and retailers (Figure 4.8). The cabbage growers acquire the necessary supplies from suppliers and hire laborers from their own families or local areas to grow cabbage. It takes 3 to 4 months to harvest the cabbage from their own farms to reach the consumers through the collectors. The collectors gather the cabbage from one or more growers and distribute them to their customers. Collectors either pick cabbage directly from farms or wait for growers to deliver to their warehouse. There is no grading or sizing for cabbage at the collecting center in the market. They just observe the external quality and other defects from pests and then they give the price for the cabbage to the growers. Most growers cannot negotiate the price from collectors. Between the collectors and wholesalers, there is a transporter to transport the cabbage to wholesale markets. Then wholesalers buy large quantities of cabbage from growers and distribute the cabbage to retailers. The retailers are the merchants in markets who sell cabbage to consumers (Figure 4.8).

#### **4.1.4.3 Good Agricultural Practices (GAP) for Cabbage in Thailand**

The GAP system for cabbage in Thailand requires farm records at all stages of cabbage farming. It also restricts the use of pesticides and chemicals to those that are acceptable to importing countries and requires these pesticides and chemicals to be used in the correct manner and to the necessary extent. It also requires the appropriate storage of agricultural chemicals to avoid environmental damage. Moreover, environmental friendly and attentive crop caring practices are promoted and the proper use of harvesting and post-harvest methods and techniques are enforced, including the implementation of accurate grading methods for the harvested cabbage. After introducing the GAP system, the Department of Agriculture (DOA) staff monitors the growers' practices on a regular basis. If growers are found to have fully complied with the GAP system requirements they are awarded a GAP certificate by the DOA. From our survey in 2010, a few cabbage growers in the 'Phu Tab Berg area' in Phetchabun province had already been certified (22%).

**Table 4.11** Characteristics of cabbage growers, 2010.

Variables	GAP (N=11)	Conventional practices (N=39)
<i>Characteristics of the person responsible for farming decisions</i>		
Growers, hill tribe (%)	100	100
Male (%)	100	96
Age (years)	35.1	38.7
<i>Education level</i>		
Primary school or less	63.6	69.3
Secondary school	36.4	30.7
<i>Farm and household characteristics</i>		
Contract farming system (%)	57.1	0
Production planning (%)	100	56
Cabbage planting area (rai)*	6.2	5.6
Number of varieties grown	1	2
Cabbage farming experiences (years)	8.5	13.5
Packaging materials, PE bag with holes (%)	100	100
Mode of transport, pick-up truck (%)	100	100

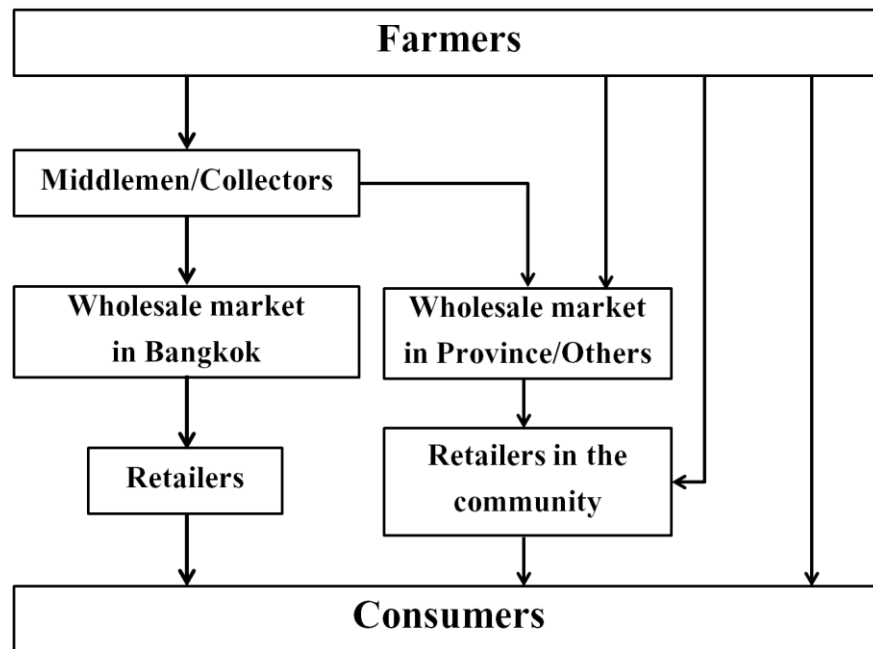
Source: Field survey, 2010

Note: \*1 rai equals approximately 0.16 hectares.

#### 4.1.4.4 Cabbage Production in Phetchabun Province

Cabbage was produced usually three times a year. About 22% of the growers were GAP-certified. For those who did not follow GAP, there were two main reasons: the selling price of GAP and conventional practice cabbage was not different and the GAP process is difficult and they are not concerned with GAP certification. However, cabbage yield from GAP farms (7,700 kg/rai) was higher than that from conventional practice farms (6,200 kg/rai) (Table 4.12). The price of GAP or conventional practice produced cabbages did not differ. It depended on the daily demand and supply of cabbages and it highly fluctuated at the collecting centers in the markets. All cabbage growers were not engaged in any contract farming schemes. The growers directly

contacted the collectors at the market's collecting center. The supply chain process of sourcing mainly involved farm inputs, such as seeds, fertilizers, herbicides, pesticides and other necessary materials. Seeds were purchased from shops (80%) or from a private company (20%). The selection of the cultivars to grow was mainly based on advice from the private company extension officers (64%), while for others based it on experience (22%), vendors (6%), or suggestions from neighbors (4%). There were three popular cultivars being grown: 'T-530' (46%), 'T-523' (41%), and 'T-593' (11%), all of which were demanded by markets. Fertilizers and other farm inputs were purchased from shops. The first step of production was the raising of seedlings for field planting when they were one month old. Prior to field planting, the land was prepared to clean the area and make the soil suitable. During the first 7 days of field planting, fertilizer was applied. The plants were rainfed during the rainy season or supplied with water through a canal during the dry season. Chemicals used were mainly insecticides and herbicides, which were usually applied when pests were found in the area. Cabbages were harvested in the early morning or late afternoon. The most commonly used maturity index (92%) was compactness. Cabbage size may range from 1.0-2.0 kg. Various sizes of cabbage heads were packed in perforated polyethylene bags at 10 kg/bag and loaded into big bamboo baskets for loading into a mini truck (pick-up). Growers delivered their produce to the collectors at collecting centers in the markets with a distance ranging from 30-40 km. Despite the long distance, damage to the produce was not significant since the cabbage heads had several wrapper leaves for protection. Normally the collectors bought all the produce from the growers. No grade standard was used and only insect and disease damage was of concern to collectors. Figure 4.8 illustrates the marketing channel in the cabbage supply chain that involved growers, collectors, wholesalers, retailers and consumers.



**Figure 4.8** Cabbage marketing channels in Phetchabun province, Thailand.

#### 4.1.4.5 Costs and Returns of Cabbage Growers Based on Farming Systems

The vegetable growers of Thailand are increasingly concerned about rising competition in domestic and export markets. The cost of production of cabbage is presented in this area. According to our survey, we found that growers who followed the GAP system could produce higher yields than growers who produced the cabbage with conventional practices (about 1,500 kg/rai). After harvesting, the growers sell their produce to the collectors with an average of about 3.5 Baht/kg (Table 4.12). There is no grade and standard to differentiate between the price of cabbage from GAP or conventional practice produces. In addition, the production costs of cabbage in conventional practice certified farms are higher than GAP certified farms; the production cost was about 11,458 and 8,862 Baht/rai, respectively, as shown in Table 12. Islam et al. (2012) have been reported that the cost of pesticides used in the tomato farm under conventional practice were 2 times more than GAP certified farms. Moreover, the cabbage growers who followed GAP could get more profit than that of conventional growers or a conventional practice certified farm due to higher yield and less cost of production (Table 4.12). This means that GAP certified farms can earn more money (7,846 Baht/rai) from their produce than the conventional practice farms.

**Table 4.12** Cost and return of cabbage growers based on the farming systems.

Variables	GAP (N=11)	Conventional practices (N=39)
Yield (kg/rai)	7,700	6,200
Price (*Baht/kg)	3.5	3.5
Total production costs (*Baht/rai**)	8,862	11,458
Profit (Baht/kg)	2.35	1.65

*Source: Field survey, 2010*

*Note:* Mean values are shown, \* 29.7 Baht  $\approx$  1 USD, \*\* 1 rai  $\approx$  0.16 hectare

#### 4.1.4.6 Costs and Returns of Cabbage Growers Based on Farm Sizes

There are of course variations in the costs of individual cabbage farms in Thailand and costs of production vary from season to season. The underlying variation in the cost structure of Thai cabbage farming is a key component in any assessment of assisted structural adjustment as a response to a period of low prices. This variation needs to be understood to the maximum extent possible in regards to region, farm size, and management type within the same farm size/region. In the survey from the cabbage growers, we found that the size of farms was highly significant in yield, price, production cost and profit of cabbage production in Phetchabun province, Thailand. The cabbage growers were divided into 3 difference sizes: small farms ( $\leq 3$  rai), middle farms ( $>3-6$  rai) and large farms ( $>6$  rai). The highest yields of cabbage production were found in small farms (7,900 kg/rai) while the middle and large farms were only about 6,400 kg/rai (Table 3). In addition, the price of cabbage was also the significantly highest in small farms when compared with other farm sizes (Table 4.13). This depended on the quality and daily demand and supply of cabbages highly fluctuating at the collecting centers in the markets. The production cost of middle farms was the most effective when compared with other farm sizes. However, the small farm size still had less costs of production than the large farm size (Table 4.13). The large farm size used mainly inorganic fertilizer as well as pesticides for their farms. Therefore, the cost of production in large farm size was higher than that of medium farm size. Additionally, small farm size used their own members to manage their farms and saved in the cost of production as well. Rahman and Takeda (2007) have reported the similar characteristics in the production elements between small and medium growers; the differences of the

costs of production are not great. However, the big differences of the costs of production between small-large and medium-large are because of credit purchased inputs at higher prices than cash prices by small and medium growers. The profits of cabbage growers in small farms were higher than growers in middle and large farms (2.19, 2.17 and 1.72 Baht/kg), respectively.

**Table 4.13** Costs and profits of cabbage growers based on farm sizes.

Variables	Small <sup>a</sup> (N=10)	Medium <sup>b</sup> (N=28)	Large <sup>c</sup> (N=12)
Yield (kg/rai)	7,900	6,400	6,400
Price (*Baht/kg)	3.5	3.5	3.5
Total production costs (*Baht/rai**)	10,314	8,500	11,412
Profit (Baht/kg)	2.19	2.17	1.72

*Source: Field survey, 2010*

*Note:* Mean values are shown, \* 29.7 Baht  $\approx$  1 USD, \*\*1 rai  $\approx$  0.16 hectare <sup>a</sup>

<sup>a</sup>=small farms ( $\leq 3$  rai), <sup>b</sup>=middle farms ( $>3-6$  rai) and <sup>c</sup>= large farms ( $>6$  rai)

#### **4.1.5 Consumer Preference of Cabbage Quality in High-End Markets**

Consumer preference is the most important factor to improve the cabbage quality to meet the consumer's needs. One-hundred cabbage consumers in Thailand were interviewed in order to better understand consumer preferences. The data of Thai consumer's preference was collected. Most respondents were female (84%) (Table 4.14). The respondents had varied educational attainment varying from primary school or less to university level. However, the contributions of educational background were almost the same: primary school or less was about 39%, secondary school and for university were 30% and 31%, respectively. The number of members in their family ranged from  $\leq 3$  to 6 people (90%). The results from the data survey found that the majority of family sizes in Thailand were small to middle size.

**Table 4.14** Demographic information of cabbage consumers in Thailand.

<b>Variables</b>	<b>Consumers (N=100)</b>
<i>Sex</i>	
Male (%)	16
Female (%)	84
<i>Education levels</i>	
Primary school or less (%)	39
Secondary school (%)	30
University level (%)	31
<i>Number of members in their family (%)</i>	
≤3 people (small)	42
4-6 people (middle)	48
>6 people (large)	10

*Source: consumer survey, 2010.*

As the results from survey data, most consumers' preferences were focused on sanitation ( $4.00 \pm 0.08$ ), freshness ( $3.91 \pm 0.09$ ), chemical residue ( $3.52 \pm 0.08$ ), compactness ( $3.48 \pm 0.14$ ), price ( $3.38 \pm 0.09$ ), defects ( $3.25 \pm 0.10$ ), as well as size ( $3.05 \pm 0.05$ ) of cabbage head (Table 4.15). According to the family size in Thailand as above mentioned therefore, the preference size of cabbage varied based on family size. However, the weight of cabbage head was not the most important factor in decision making for consumers. The head color of cabbage was also studied. There are two colors of cabbage head in the market. 51% of consumers preferred white cabbage, while the other 49% preferred green cabbage. There were no significant differences between the two groups. All information from the consumers was analyzed in order to design a quality management system for cabbage to meet the consumer's need.

**Table 4.15** Consumer preferences for fresh cabbage in Thailand.

<b>Variables</b>	<b>Consumers focus</b> (N=100)
<i>Preference Parameter</i>	
Freshness	3.91±0.09
Sanitation	4.00±0.08
Size of head	3.05±0.05
Weight of head	1.82±0.06
Compactness	3.48±0.14
Appearance (shape)	2.91±0.07
Brand of products	2.49±0.10
Farm location	2.50±0.10
Defects	3.25±0.10
Chemical residue	3.52±0.08
Price	3.38±0.09
Head color	
-White (%)	51
-Green (%)	49

*Source: consumer survey, 2010*

*Note:* Mean values are shown. Rating scale: 1=unimportant, 2=slightly important, 3=important, very important, and 5=critical.

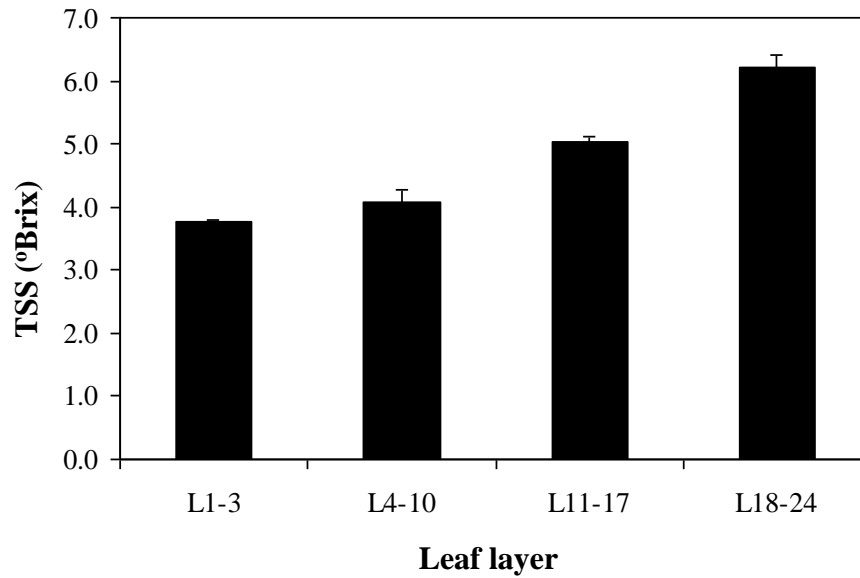
## 4.2 Quality Management of the Cabbage Supply Chain

### 4.2.1 Nutritional Quality Differences of Leaves in a Cabbage Head

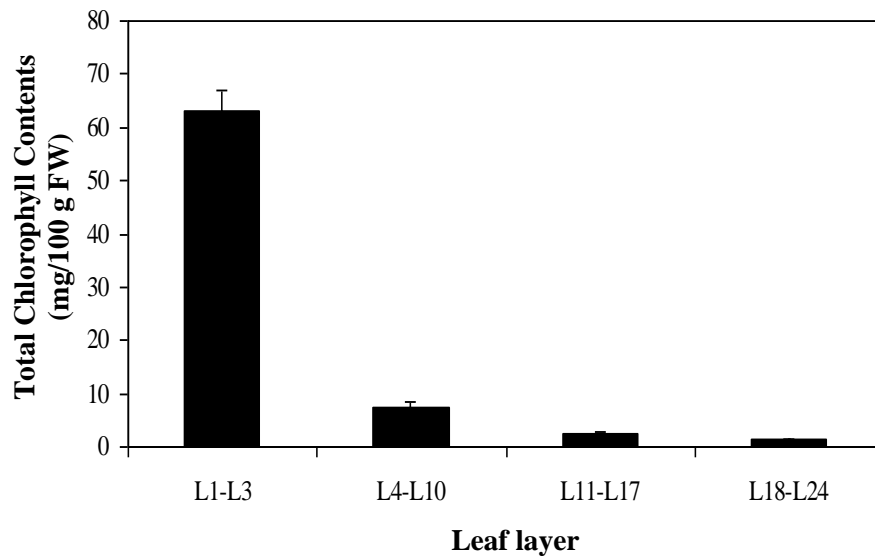
Chlorophyll content decreased with increasing internal positioning of leaves in the cabbage head (Figure 4.10). It was highest in the outermost leaves, L1-L3 (63.11 mg/100 g FW), much lower in the outer-middle leaves, L4-L10 (7.40 mg/100 g FW) and inner-middle leaves, L11-L17 (2.57 mg/100 g FW), and lowest in the innermost leaves, L18-L24 (1.32 mg/100 g FW). Carotenoid content followed the same trend as that of chlorophyll content and was about 6.0, 0.7, 0.25 and 0.15 mg/100 g FW in the outermost, outer-middle, inner-middle, and innermost leaves, respectively (Figure 4.11). The effects of leaf position on chlorophyll and carotenoid contents were anticipated since outer leaves are more exposed to light for chlorophyll formation and photosynthetic processes. Along with the chlorophylls in the chloroplasts are the carotenoids which mainly function to protect the chlorophyll from photo-oxidation as well as to capture the light energy and transfer it to the chlorophyll for photosynthesis (Mayfield et al., 1986). The carotenoid content (pro-vitamin A) obtained in the present study was higher than that of previous studies. Hart and Scott (1995) obtained carotenoid contents of only 0.103 mg/100 g FW for 'Savoy' cabbage and 0.08 mg/100 g FW for green cabbage. In Brussels sprouts, carotenoid contents ranged from 0.185-0.92 mg/100 g FW (Heinonen et al., 1989; Granado et al., 1992), while in leaf beet and turnip greens from 1.5-5.6 mg/100g FW (Granado et al., 1992). Furthermore, during the postharvest period, much of these nutritional constituents (i.e. chlorophyll and carotenoids) are lost since trimming is usually done to remove damaged and diseased parts that affect most the outer leaves (Prange and Lidster, 1991).

Total ascorbic acid (vitamin C) content was highest in the outermost leaves (22.61 mg/100 g FW) and did not differ much among the other three inner positioned leaves (15.53-16.75 mg/100 g FW) (Figure 4.12). The results compare well with the ascorbic acid contents of other leafy vegetables including black pepper, amaranth and white camwood (Chinmar and Igyor, 2007). On the other hand, total soluble solids content was highest in the innermost leaves (provide actual value) (Figure 4.9). It decreased progressively with increasing external positioning of the leaves and was about (value) in the inner-middle leaves, (value) in the outer-middle leaves, and (value) in the outermost leaves. Sugars are major components of soluble solids and they usually accumulate at

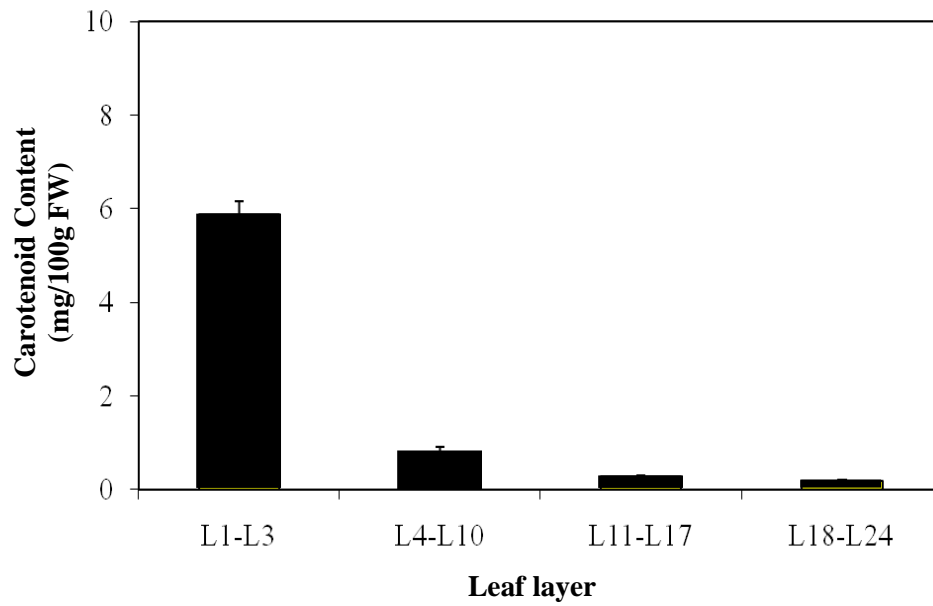
lower temperature as noted in cabbage seedlings during cold acclimation (Hidekazu et al., 1996) and in spinach exposed to low temperature (Guy et al., 1992). In cabbage heads, inner leaves have usually lower temperatures as they are protected by the outer leaves from exposure to the higher temperatures in ambient conditions.



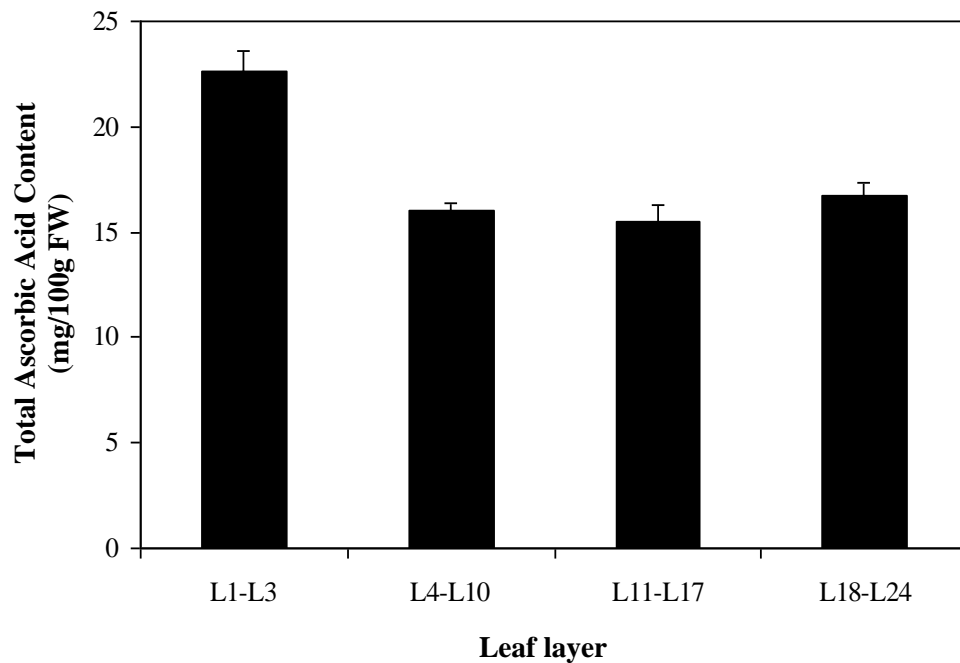
**Figure 4.9** Total soluble solids (TSS) content in different leaves of cabbage.  
(Mean of 4 replications  $\pm$ SE)



**Figure 4.10** Total chlorophyll contents in various leaves of cabbage.  
(Mean of 4 replications  $\pm$ SE)



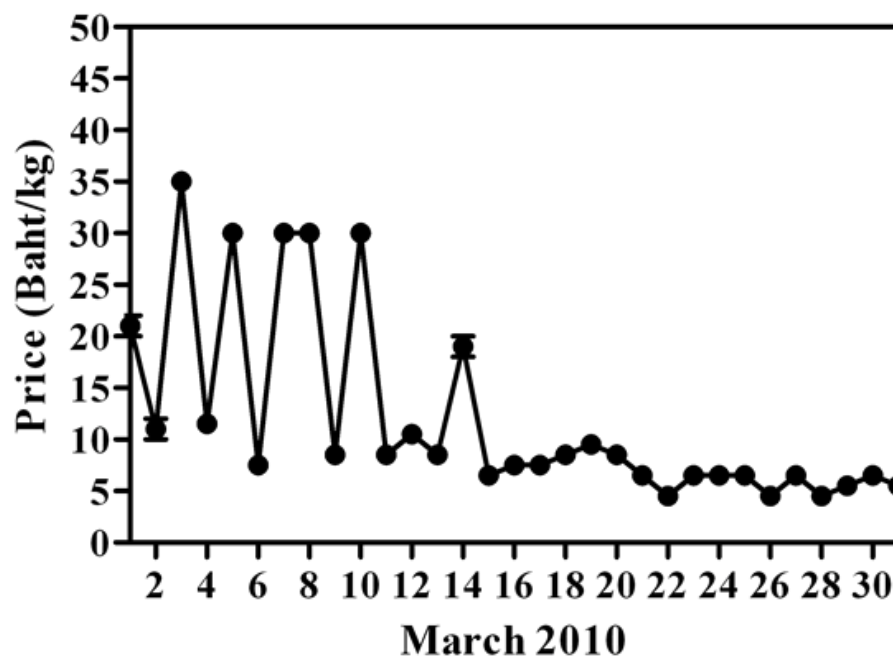
**Figure 4.11** Carotenoids content in different leaves of cabbage.  
(Mean of 4 replications  $\pm$ SE)



**Figure 4.12** Total ascorbic acid contents (AsA) in different leaves of cabbage.  
(Mean of 4 replications  $\pm$ SE)

#### 4.2.2 Effect of Storage Temperatures on Postharvest Quality of Cabbage in the Supply Chain

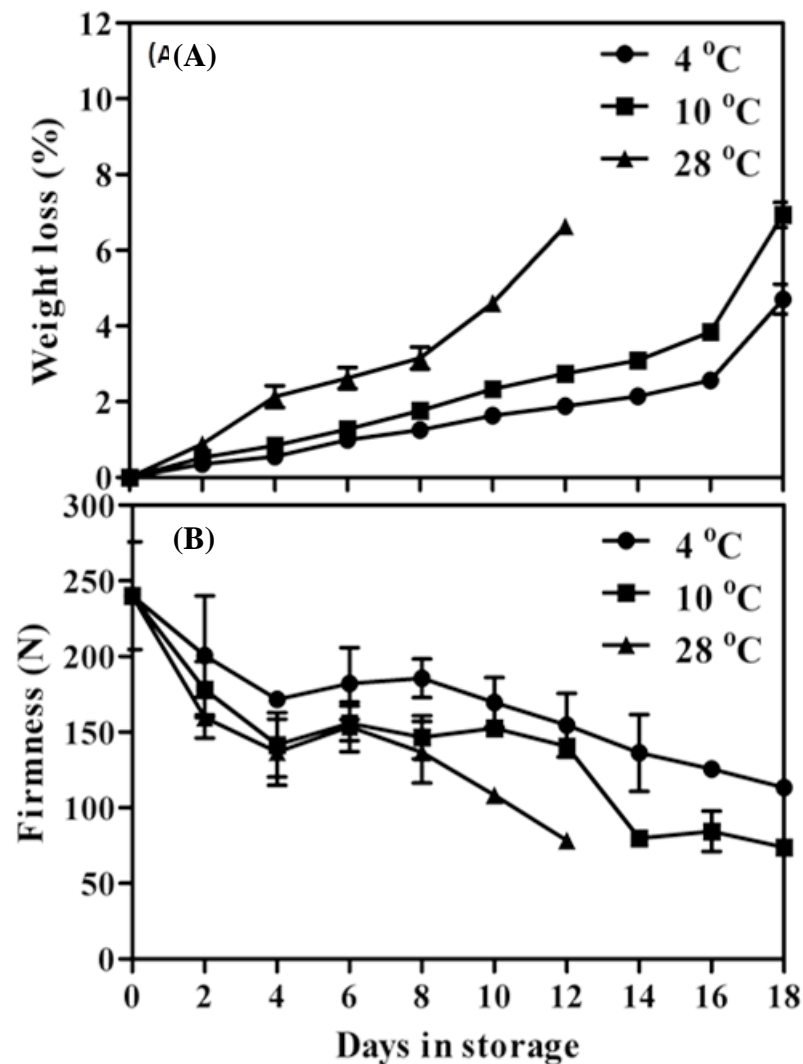
Cabbage is a highly seasonal crop with an oversupply during production peaks and undersupply during lean season, resulting in highly fluctuating prices (Figure 4.13). Cabbages reach the retail markets at least one or two days after harvest, thus the quality has significantly decreased. Therefore, maintaining the postharvest quality of cabbage at collection centers while waiting for a more favorable price is important. Low temperature or cold storage is the single most effective method of prolonging the postharvest life of fresh produce. It reduces respiration rate, ethylene production and sensitivity, moisture loss, and growth of pathogens. Its integration in the cabbage supply chain management could improve profitability and sustainability. This study was therefore conducted to determine the efficacy of low temperature storage in maintaining the quality of cabbages at the collecting stage in the supply chain.



**Figure 4.13** Price of cabbage at the collection center of Phetchabun provincial market, Thailand, March 2010. (1 USD is approximately 31.58 Baht).

#### 4.2.2.1 Weight loss and firmness

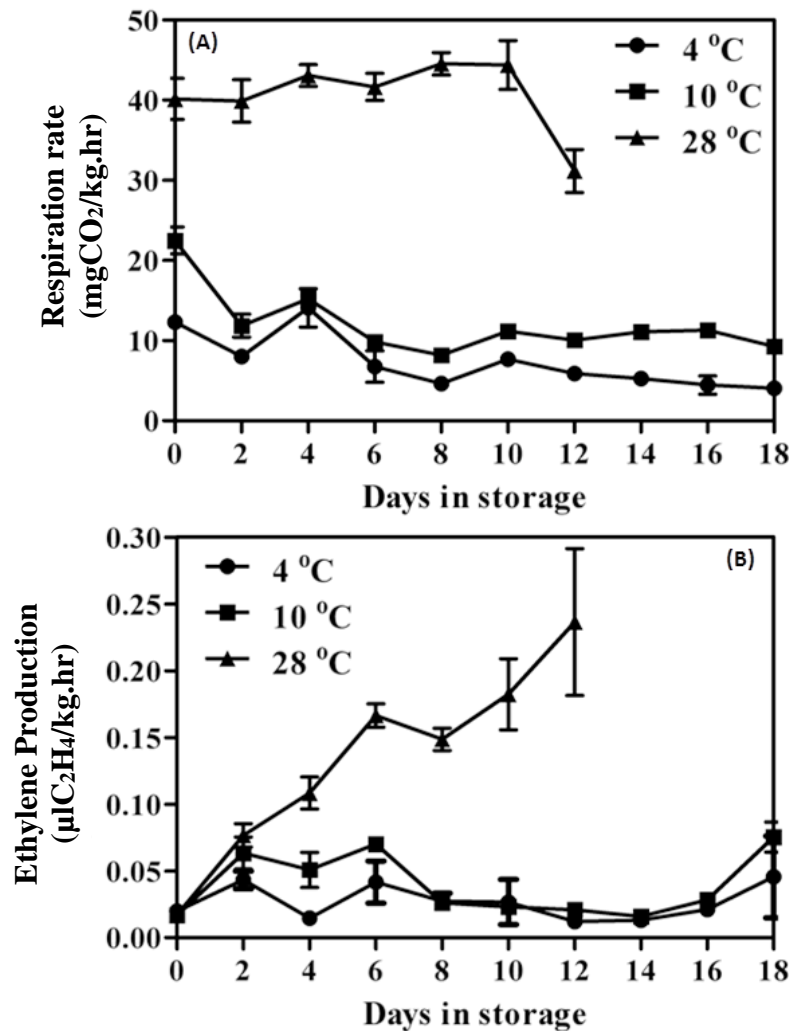
Weight loss increased with storage much more rapidly at ambient temperature (28 °C) than at 4 or 10 °C (Figure 4.14A). Cabbages held at 4 °C had the lowest weight loss throughout the storage period. On the other hand, firmness of cabbage heads decreased with storage (Figure 4.14B). It was most rapid at ambient temperature and least rapid at 4 °C. Losses in weight and firmness of cabbages could occur at any stage in the supply chain. To reduce these losses, proper temperature management is important as illustrated by the effects of low temperature obtained in the present study. Daly and Tomkins (1998) found that weight loss of Chinese cabbage was reduced at lower temperatures. At higher temperatures, vapor pressure deficit increases, resulting in increased water loss, which mainly accounts for weight and turgidity losses.



**Figure 4. 14** Weight loss (A) and firmness (B) changes in cabbages during storage at 4, 10 and 28 °C.

#### 4.2.2.2 Respiration rate and ethylene production

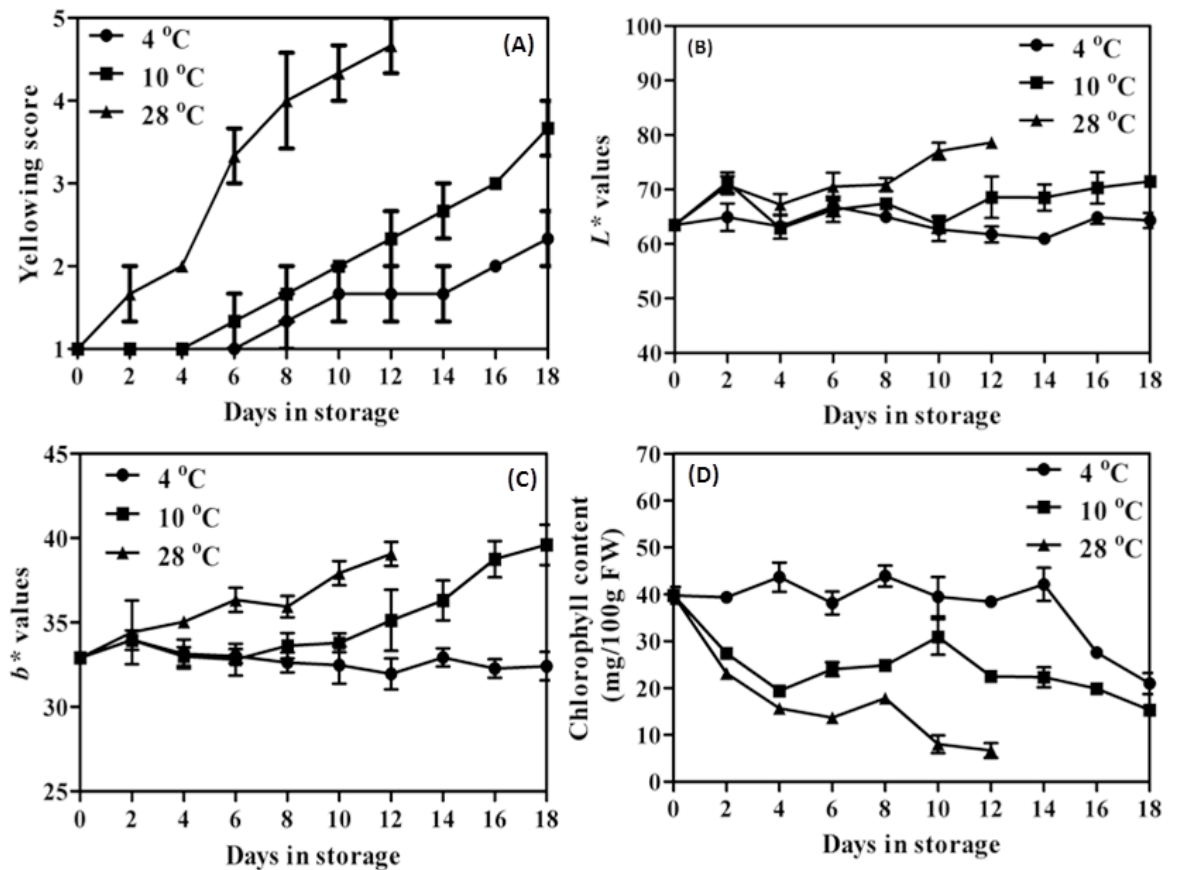
Respiration rate was about 2-3 times higher at 28 °C than at 4-10 °C throughout the storage period (Figure 4.15A). Cabbages stored at the lowest temperature also showed the lowest rate of respiration. Ethylene production increased with increasing periods of storage at ambient temperature; this was inhibited during storage at low temperatures (Figure 4.15B). These results compare well with that of previous studies. Porter et al. (2003) reported that the respiration rates of Chinese cabbage were higher at 20 °C than at lower temperatures. With the onset of senescence, respiration rates would increase dramatically. This could be accompanied by corresponding increases in ethylene production (Kader, 1992). Ethylene, even at low levels, is known to promote senescence and increased levels of production, which accelerate deterioration and shorten the postharvest life (Wills et al., 1999).



**Figure 4.15** Respiration rate (A) and ethylene production (B) of cabbages during storage at 4, 10 and 28 °C.

#### 4.2.2.3 Color changes

Yellowing of outer leaves of cabbage developed very quickly at 28 °C and was already perceptible after 2 days of storage (Figure 4.16A). In contrast, cabbages stored at low temperatures showed much delayed yellowing, with storage at 4 °C being more effective than at 10 °C. Yellowing scores (Figure 16A) were objectively supported by the  $L^*$  and  $b^*$  values which were highest at 28 °C and lowest at 4 °C (Figure 4.16B and C). Similarly, chlorophyll contents decreased with storage most rapidly at 28 °C and only gradually at 4°C (Figure 4.16D). Average chlorophyll loss was 65.6 % at 28 °C, 39.6% at 10 °C, and 4.2% at 4 °C. Chlorophyll breakdown leading to yellowing of outer leaves is the first visible sign of senescence in cabbage (Figure 4.17A and B). This has also been obtained in other leafy vegetables such as spinach (Yamauchi et al., 1985), parsley and garland chrysanthemum (Yamauchi et al., 1980), pak-choi, water convolvulus and spinach (Hirata et al., 1987), mitsuba leaves (Yamauchi et al., 1995) and jute leaves (Tulio et al., 2002). In all these studies, yellowing was more favored at higher storage temperatures.



**Figure 4.16** Yellowing (A),  $L^*$  (B),  $b^*$  values (C) and chlorophyll content (D) of cabbage during storage at 4, 10 and 28 °C.

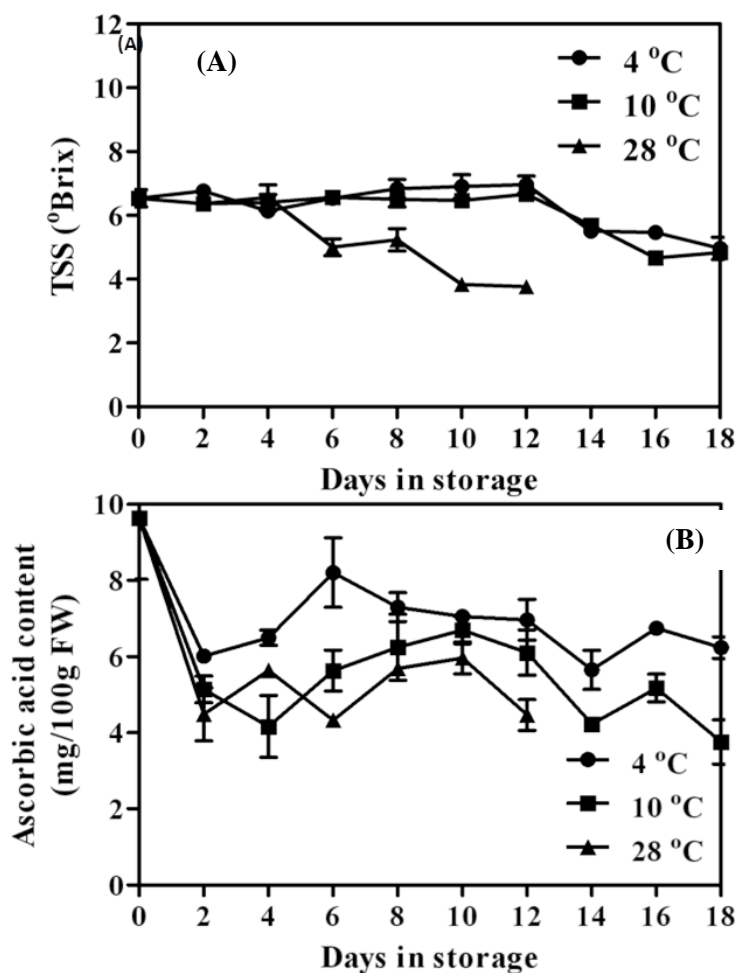


**Figure 4.17** Appearance of top (A) and bottom (B) parts of cabbage heads stored at 4, 10 and 28 °C.

#### 4.2.2.4 Total soluble solids and ascorbic acid contents

TSS content remained almost unchanged during the first 4 days of storage at all storage temperatures, but later, it decreased rapidly at 28 °C (Figure 4.18A). Such decrease in TSS occurred only after 14 days of storage at 4 °C or 10 °C; both temperatures had comparable effects. In an earlier study, decreases in fructose, glucose, sucrose and soluble solids contents were also observed in cabbage stored for 6 months at 0-1 °C (Nilsson, 1993). On the other hand, ascorbic acid content decreased after 2 days of storage and fluctuated thereafter (Figure 4.18B). However, cabbages stored at 4 °C had consistently the highest ascorbic acid content while those stored at 28 °C had the lowest. Fawusi (1983) previously reported that jute leaves stored at 4 °C lost about 77% ascorbic acid over a 4-week storage period, much smaller than those stored at ambient temperature (25-28 °C), which incurred a 93% loss within only 4 days of storage. Hirata

et al. (1987) also found that in leafy vegetables such as pak-choi (*Brassica chinensis* L.), edible amaranth (*Amaranthus mangostanus* L.), and soup celery (*Apium graveolens* L. var. *secalinum* Aleff.), the decrease in ascorbic acid contents was retarded by low temperature storage.

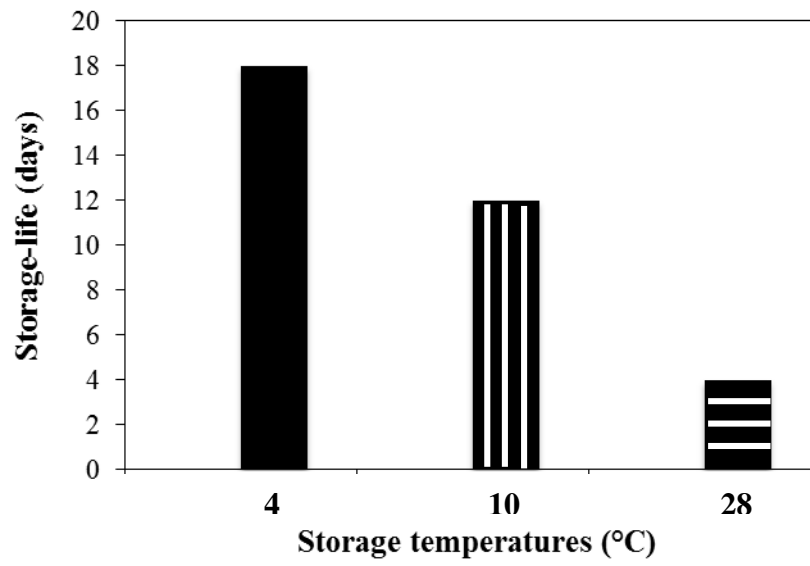


**Figure 4.18** Total soluble solids (A) and ascorbic acid content (B) of cabbages during storage at 4, 10 and 28 °C.

#### 4.2.2.5 Storage life

Low temperature storage remarkably increased storage life of cabbage (Figure 4.19). Storage life was about 18 days at 4 °C and 12 days at 10 °C, compared with only 4 days at 28 °C. The extension of storage life was due to the reduction of losses in chlorophyll and water content, thus maintaining the green color and turgidity of the leaves. Respiration rate and ethylene production were likewise retarded with low temperature storage, thus delaying senescence. In addition, low temperature storage reduced the

losses in soluble solids and ascorbic acid contents, thereby preserving the nutritional value of cabbage.



**Figure 4.19** Storage life of cabbages at 4, 10 and 28 °C.