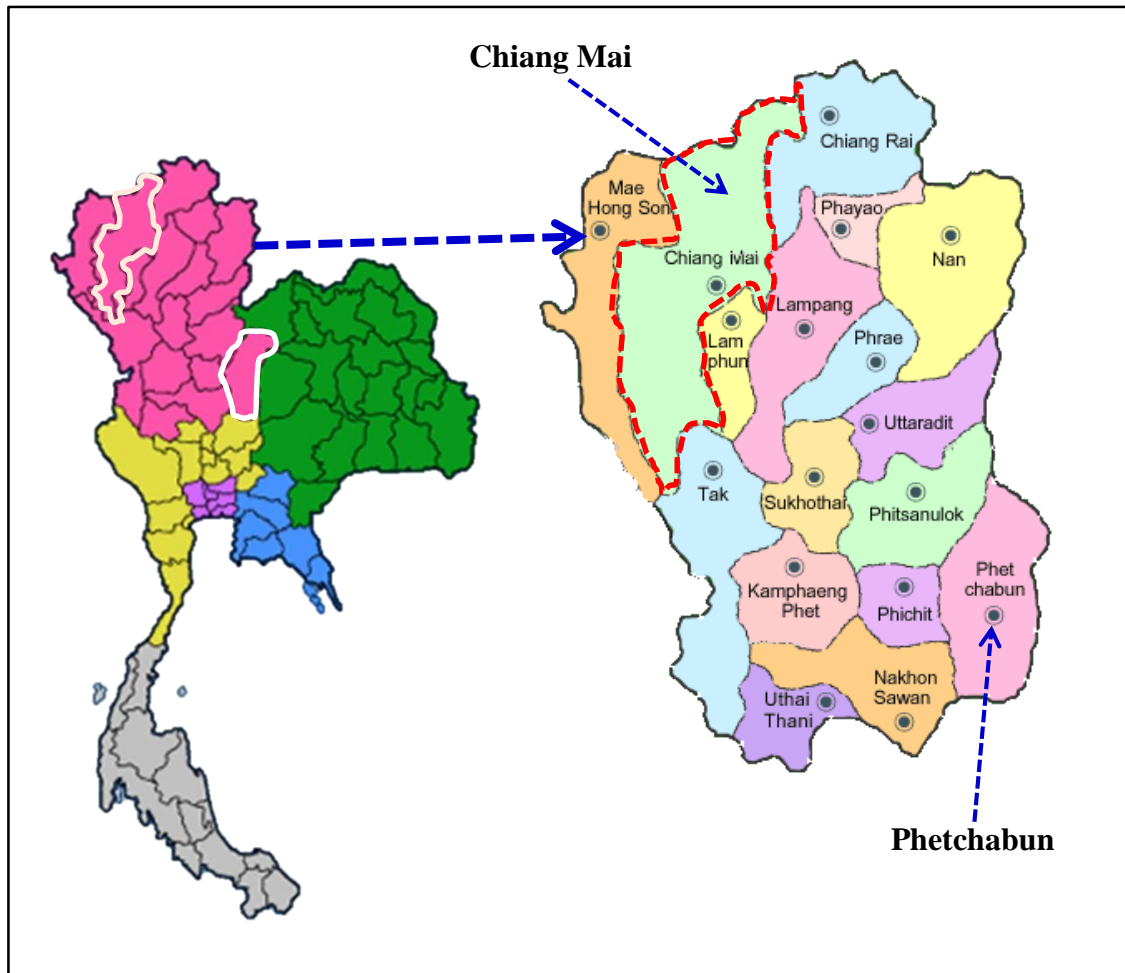


## **CHAPTER 3 MATERIALS AND METHODS**

### **3.1 The Cabbage Supply Chain Analysis**

#### **3.1.1 Mapping of Cabbage Supply Chain in Phetchabun Province and the Royal Project Foundation in Chiang Mai Province, Thailand**

Traditional and good practice supply chains for cabbage were mapped. The traditional supply chain covered the plantation areas in Phetchabun province, Thailand. This was compared with modern supply chains for cabbage in the Royal Project Foundation, Chiang Mai, Thailand. The locations of the study areas are presented in Figure 3.1. Two types of structured questionnaires were developed to gather general and specific information by supply chain actor (growers and collectors). The questionnaires were pretested and refined before conducting the survey. Following the sample size principle in determining the appropriate number of respondents, 50 growers (39 conventional growers and 11 GAP certified growers) and 7 collectors in Phetchabun province and 52 growers under Project Foundation were randomly selected to be interviewed. The survey was followed based on in-depth interviews. Face-to-face interviews were conducted in Phetchabun province and the Royal Project Foundation in Chiang Mai province, Thailand. The generic information sought included socio-demographic data, postharvest loss estimates, trading information (collaboration with other actors, product trait assessment, modes of transport used during purchase from suppliers and delivery to buyers, types of packaging materials for incoming and outgoing products), marketing information (monthly volume of quantities purchased and sold, prices achieved, main trading partners, monthly turnover of entire business), value-adding activities, and attitudes toward postharvest loss. For farmers, production and harvesting practices were also obtained based on the past year's production cycles. The questionnaires were designed based on the supply chain philosophy following the SCOR model (V.11) (Appendix 1 and 2).



**Figure 3.1** The location of the study areas (Chiang Mai and Phetchabun provinces, Thailand).

### 3.1.1.1 Data Analyses

Survey data were collected and calculated as percentages and frequencies. The findings were analyzed following the SCOR model and critical problems were identified. Based on this analysis, keys strategies for improving the existing quality management system were identified. The key strategies included technical interventions in production, harvesting and postharvest. Other techniques need to be developed, verified, and optimized before integration in order to improve quality management systems for the cabbage supply chain in Phetchabun province.

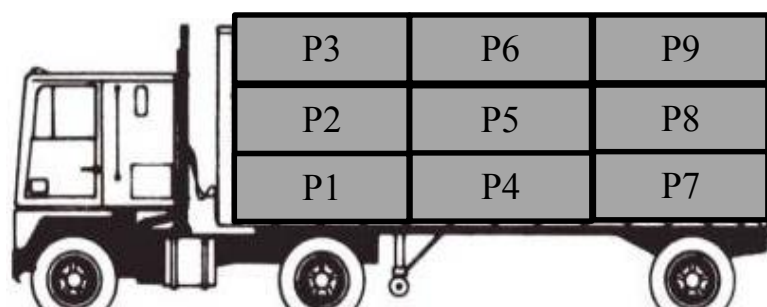
### **3.1.2 Quantifying Postharvest Losses of Cabbage in the Supply Chain in Phetchabun Province, Thailand**

The study was conducted in the production season of 2010 in Phetchabun Province, northern Thailand. The cabbage heads were harvested early in the morning at a commercial farm. 108 harvested cabbage heads were carefully tagged and packed into 9 plastic bags with holes. Each bag held 12 heads (3 heads for 0, 2, 4 and 6 wrapper leaves each). Data loggers were also put in the cabbage bags in order to record temperature and humidity data during transport (Figure 3.2). There were 2 kinds of trucks to transport the cabbages from the farm to the retail market, small truck (pick-up) and a bigger truck (6 wheels). The small truck was used from the farm to the collection center, the bigger truck for the collecting center to the wholesale market and another small truck from the wholesale market to the retail market. Moreover, the cabbage bags were positioned into different locations on the truck in order to quantify the postharvest loss of cabbage due to physical damage during transportation (Figure 3.3). The percent of physical damage loss of cabbages at the farm and wholesale and retail markets were estimated.



**Figure 3.2** Preparation for transport practices from farm to retail market.

(1=harvesting cabbage, 2=weighing and tagging, 3=putting data logger into the bag, 4=labelling the bag, 5=loading to each positions, 6=ready for transport)



**Figure 3.3** The sketch of positioning of cabbages on the truck during transport from farms in Phetchabun province to wholesale and retail markets in Bangkok, Thailand.

### **3.1.3 Cost Analysis of Cabbage Supply Chains in Phetchabun Province and the Royal Project Foundation, Chiang Mai, Thailand**

The structured questionnaire was designed for collecting the data from 102 growers and 7 collectors for the cabbage supply chain with face to face interviews. The total cost analysis of cabbage supply chain were calculated. Statistical analysis was performed using SPSS for windows software version 17. Data was analyzed by one-way fixed analysis of variance (ANOVA). Duncan's multiple range test was used for mean comparison at a significance level of  $P < 0.05$ .

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

This study adopted the case study method to obtain the necessary data on the farming system of both GAP-practicing cabbage farmers and those of conventional farmers (non-practicing of GAP). The study took place in the 'Phu Tab Berg' area in Phetchabun province, northern Thailand. This is the most important area for cabbage production in Thailand. The GAP-practicing cabbage farmers were selected from this region. The effectiveness of farm sizes was also studied. The farm sizes for cabbage production were divided into 3 groups: small scale farmers ( $\leq 3$  rai), medium scale farmers ( $\geq 3-6$  rai), and large scale farmers ( $> 6$  rai). The survey was conducted between June and August of 2010. On-site visits were then conducted to interview the 50 cabbage farmers and gather initial information on existing practices and constraints. Several interviews were conducted in Thai using a structured questionnaire specific for

this research by trained enumerators from King Mongkut's University of Technology Thonburi, Thailand.

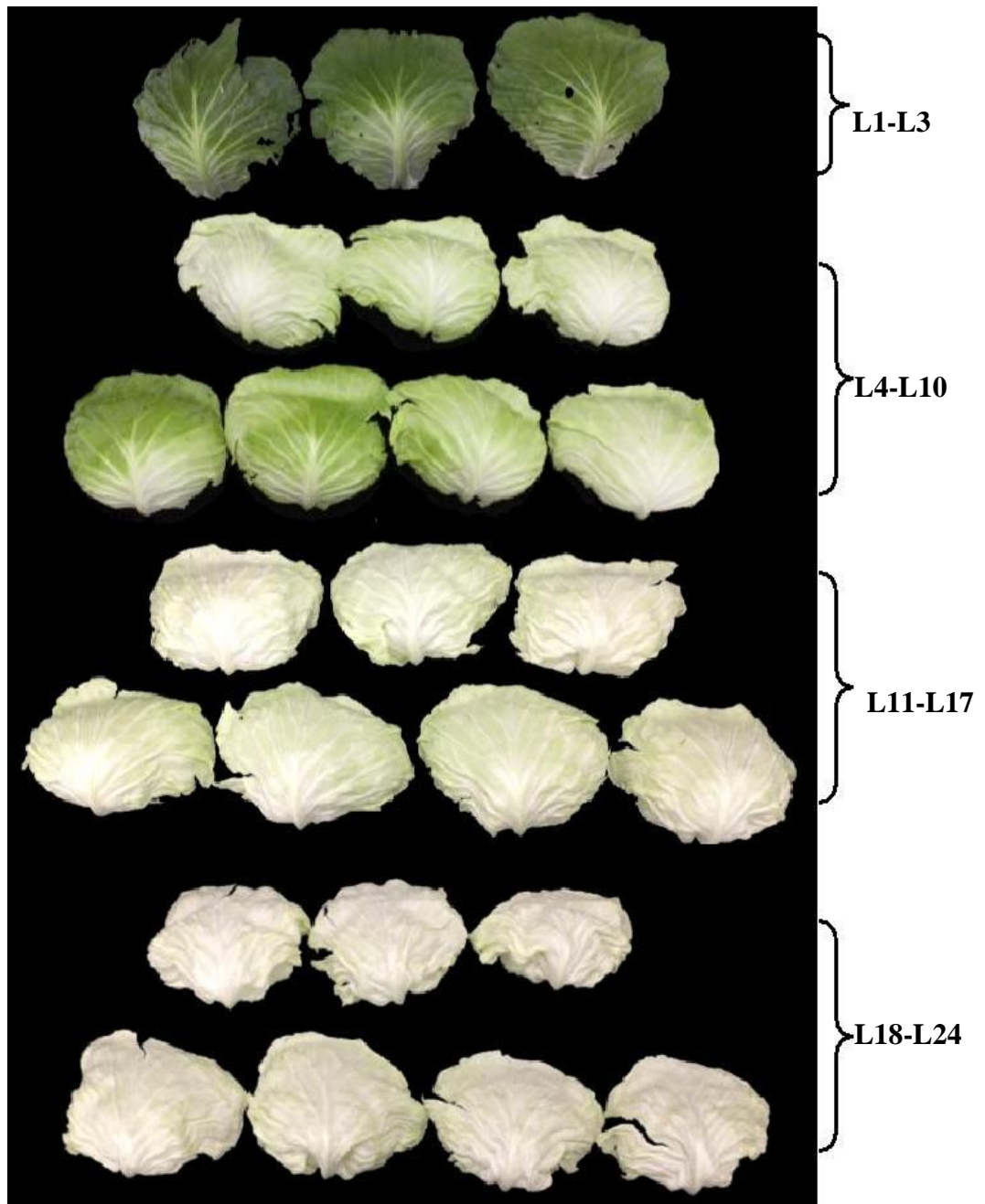
### **3.1.5 Consumer Preference of Cabbage Quality in High-End Market**

The structured questionnaire was also designed to determine consumer perceptions (Appendix 3). One hundred cabbage consumers were randomly selected for interview. Statistical analysis was performed using SPSS for windows software version 17.0. Data was analyzed by one-way fixed analysis of variance (ANOVA). Duncan's multiple range test was used for mean comparison at a significance level of  $P < 0.05$ .

## **3.2 Quality Management of Cabbage**

### **3.2.1 Estimation of Nutritional Quality in Different Leaf Layers of Cabbage**

The cabbage heads were harvested in the early morning at commercial maturity stage (90 days after transplanting) from a farm in Phetchabun province, Thailand, and then transported to the Postharvest Technology Program Laboratory, King Mongkut's University of Technology Thonburi, Bangkok, about 350 km away. The experiment was carried out with four replications of cabbage head. The cabbage heads were carefully separated into individual leaves by hand into four groups (L1-L3, outer leaves; L4-10 and L11-L17, middle leaves; and L18-L24, inner leaves) and then the nutritional contents and quality were quantified (Figure 3.4). The contents of chlorophyll, carotenoid, total ascorbic acid and total soluble solids (TSS) contents in the different leaves of cabbage were examined.



**Figure 3.4** The cabbage leaves were divided in to 4 groups.

### **3.2.2 Effect of Storage Temperature on Postharvest Quality of Cabbage in the Supply Chain**

Cabbage (*Brassica oleraceae* var. *capitata* L.) heads at commercial stage (90 days after planting), with compact heads were harvested from a commercial farm in Phetchabun province, Northern Thailand. The heads were selected for uniformity of size and color. Heads were then randomly divided into three groups and each group was packed into PE bags with holes in the field. Individual PE bags (commercial used) contained approximately 10 kg of cabbage. The bags were transported to the laboratory under temperature-controlled conditions (23-25 °C) within 6 h. The bags were stored at 4, 10 or 28 °C (95±1% RH). The samples were taken at 2-day intervals to observe the physiological and biochemical characteristics of the leaves' yellowing changes of whole cabbage head during the postharvest period.

#### **3.2.2.1 Measurement of color changes**

Leaf yellowing was estimated by measuring the extent of the total yellow area on each leaf surface using the following scale: 1=no yellowing and 5=fully yellowing of the leaf surface. When the leaves reached a score >3, they were considered unmarketable. Changes in leaf color were measured using a Minolta Chroma meter (model CR-400, Osaka, Japan). The meter was calibrated using the manufacturer's standard white calibration plate. The colors were expressed as  $L^*$  and  $b^*$ .  $L^*$  value refers to the lightness, ranging from 0 = black to 100 = white. Negative (-) and positive (+) values of  $b^*$  refer to blue and yellow colors, respectively. The chlorophyll contents were extracted from cabbage leaves with *N, N* dimethylformamide (1:20, w/v) and chlorophyll content was determined according to Moran (1982). The extraction process was carried out for 24 h at 4 °C in the dark to minimize photodegradation of chlorophylls, and the quantification was performed with a spectrophotometer (UV-1800 Shimadzu Kyoto, Japan). The chlorophyll content was expressed as mg/100 g of fresh weight.

### **3.2.2.2 Weight loss and firmness measurement**

The fresh weight of each cabbage head was monitored every 2 days and data were expressed as percent of weight loss. Head firmness was measured on the top sides of each head using a texture analyzer (TA-XT2, Stable Micro Systems Ltd., UK) with a 5 mm diameter plunger with a constant moving rate of 20 mm.min<sup>-1</sup> for a 5 mm depth. The mean values for maximum force are reported in Newton (N).

### **3.2.2.3 Measurement of respiration rate and ethylene production**

The ethylene production of the whole cabbage head was measured with a GC-2014A (Shimadzu, Japan) equipped with a 80/100 mesh Porapack Q column and a flame ionization detector (FID). A cabbage head was placed in 4 L sealed plastic chambers filled with gas sampling ports and incubated at storage temperatures (4, 10 or 28 °C) for 2 h. A 1 mL gas sample was withdrawn from the headspace for ethylene determination. Respiration rate were determined by using a GC-8A (Shimadzu, Japan) filled with a 80/100 mesh Porapack Q column and a thermal conductivity detector (TCD) (Gemma et al., 1994).

### **3.2.2.4 Total soluble solids (TSS)**

Total soluble solids (TSS) were measured using a digital refractometer (PAL-1, Atago, Tokyo, Japan). The units of TSS were expressed in degree of brix (°Brix). All head quality measurements were done in 3 replications.

### **3.2.2.5 Total ascorbic acid analysis**

The total ascorbic acid (AA) or vitamin C content was measured according to the method of Hashimoto and Yamafuji (2001). Five gram samples of leaves were mixed with 20 mL of cold 5% metaphosphoric acid and filtered through Whatman No.1 paper. A 0.4 mL aliquot of the filtrate was mixed with 0.2 mL of 2% *di*-indophenol. The mixture was then added to 0.4 mL of 2% thiourea and 0.2 mL of 1% dinitrophenol hydrazine, and incubated at 37 °C for 3 h. After incubation, 1 mL of 85% sulphuric acid was added, and the resultant solution was incubated again at room temperature for 30 mins. Total ascorbic acid was determined by measuring absorbance at 540 nm by a spectrophotometer (UV-1601; Shimadzu Co., Kyoto, Japan). The concentration of total ascorbic acid was expressed as ascorbic acid on a fresh weight basis, mg/100 g.

### **3.2.2.6 Statistical analysis**

The experiment was laid out in a completely randomized design (CRD) with three replicates. Analysis of variance (ANOVA) was performed using SPSS for windows software version 17.0. Treatment means were compared by Least Significant Difference (LSD) test at  $P \leq 0.05$ . Treatment means are also presented with standard error (SE) values.