CHAPTER 2 LITERATURE REVIEW

2.1 An Overview of Vegetables Production

The production of vegetables is spread throughout all regions of the world. According to FAO data, the total production of vegetables in the world in 2007 was estimated to be 908.8 million metric tons (MMT) (Figure 2.1). China alone produced about 50% (451.6 MMT) of world production, followed by India (77.2 MMT), the United States (38.8 MMT), Turkey (25.7 MMT), and the Russian Federation (16.6 MMT). The top ten vegetable producing countries (Table 2.1) contributed about 75% of the vegetables produced in the world. Obviously, there is a lot of scope for increasing vegetable production in all parts of the world. Alongside fresh vegetables, which are a mainstay of developing economies, there is also demand and need to diversify and develop postharvest storage, transport and processing infrastructure to extend the use of vegetables beyond their growing seasons and regions. Many Western countries have developed vegetables suitable for cold climates, including potatoes and tomatoes. Among the tropical regions, China, India, Brazil, Pan American countries and countries of Africa, Central Asia and Southeast Asia have climate and resources suitable for the growth of many types of vegetables. Recent efforts in these countries have emphasized improving the agronomic practices and development of high yielding good quality vegetables for domestic and export markets (Nirmal et al., 2010).

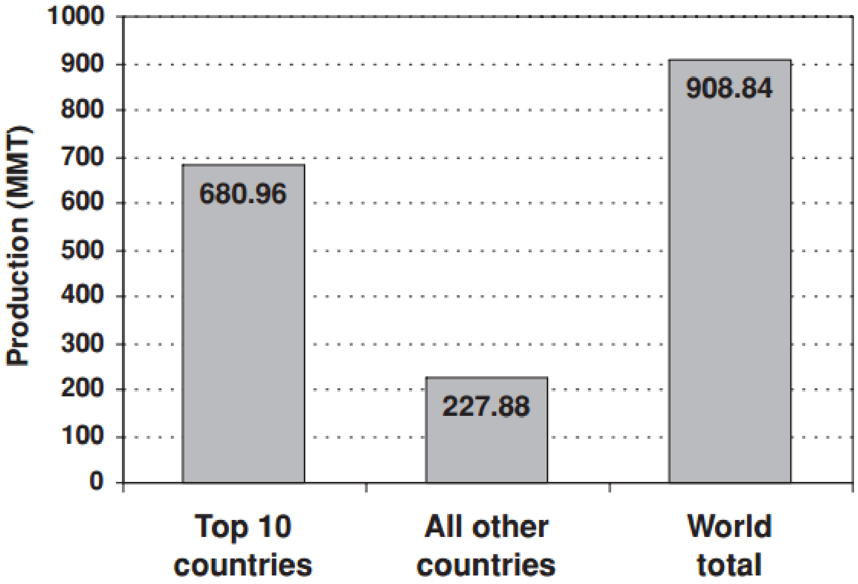

Figure 2.1 Vegetable production (including melons) in the top ten producing countries and world (2007) (Nirmal et al., 2010).

Table 2.1 Vegetable production in leading countries (2007)*.

Country	Production (million metric tons)
China	451.63
India	77.24
USA	38.85
Turkey	25.71
Russian Federation	16.58
Egypt	16.04
Iran	15.99
Italy	13.50
Spain	12.72
Japan	12.70

Source: FAOSTAT (http://faostat.org), Accessed on June 22, 2010. *Including melon.

2.2 Leafy Vegetables

Leaves are the primary site of photosynthesis in plants and are generally the most nutrient dense and most perishable. Leaves, particularly dark green leaves, contain relatively high levels of minerals (e.g., Fe, Mg, Ca), enzymes (protein) and secondary metabolites (e.g., carotenes and xanthophylls). These compounds, which are important to human diet, are required by the light collection, electron transport system, carbon fixation, and several biochemical processes that are abundant in leaves. Stomata are especially dense on the abaxial surface of leaves and the terminal point of transpiration, which is the primary mechanism for dissipating heat accumulated from intercepting solar radiation. High stomatal density combined with high surface area make leafy vegetables more susceptible to postharvest water loss than other vegetables. Subsequently, rapid cooling after harvest and storage under high humidity are particularly important postharvest procedures for leafy vegetables (Kader and Rolle, 2004).

2.2.1 Quality components of leafy vegetables

Leafy vegetable quality is mainly based on appearance (e.g. fresh-looking, well-formed or well-shaped, right size, right maturity, right color, turgid or not wilted, free of defects such as rot, physical damage, yellowing, or wilting) and to a certain extent, other attributes that cannot be seen but can be felt by the other human senses, such as firmness, tenderness, and taste. For common cabbage and Chinese cabbage, the heads should be light green, compact but not over-mature (no seed stalk), the right size, and free of defects. The anatomy of selected leafy vegetables is presented in Figure 2.2. Freshness of cabbages can be tested by rubbing two heads together; if they are fresh, they will make a squeaking sound (Nirmal et al., 2010).

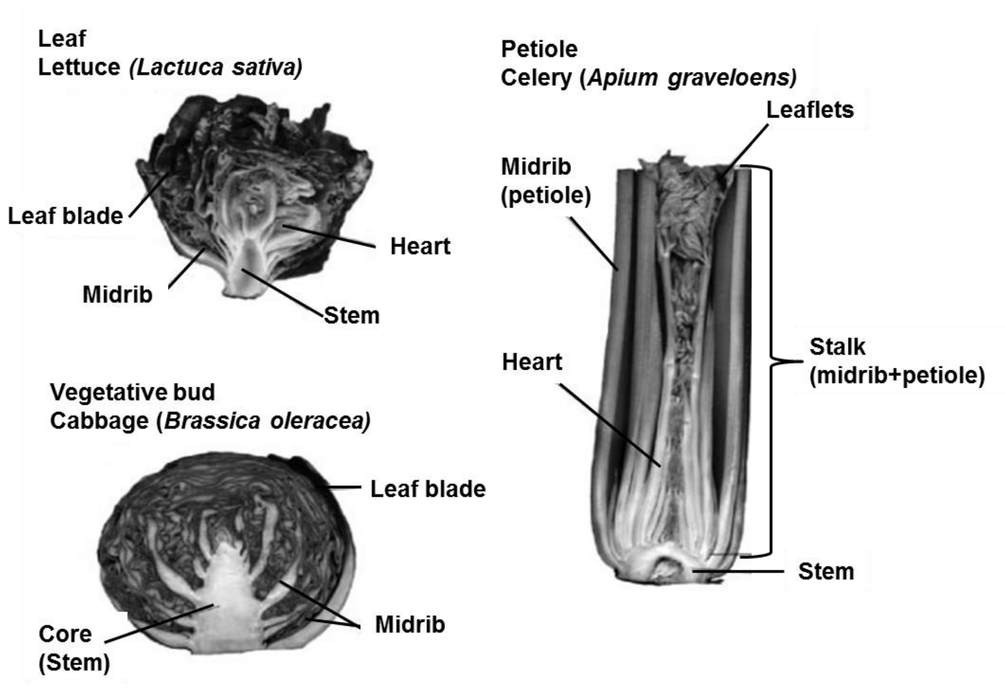

Figure 2.2 Anatomy of select leafy vegetables (Nirmal et al., 2010).

2.3 Cabbage Production

2.3.1 General information

Cabbage has been cultivated for many years and was highly valued by the Greeks and Romans, who may have introduced this vegetable into Europe. Cabbage is now one of the most cultivated vegetables in temperate climates. Although the majority of cabbage cultivars are of the green (white) type, there are cultivars that have red or purple leaves and others, such as the Savoy types that have wrinkled leaves. The most important types of cultivated cabbage are the green (i.e., domestic, Danish, conical, or pointed-head types), red, and Savoy types. The green cabbage is the most important class and is grown mostly as an early to mid-season crop. This group includes cultivars with round or slightly flattened heads that are characterized by tender and brittle leaves. The leaves of the domestic type are a little crinkled or curled and do not overlap as much as the ones in the Danish type, forming a less compact head. The Danish types are usually late in maturing and have a solid, round to oval-shaped head, and the leaves are usually smooth and closely compact. The red types produce compact heads with reddish or purplish tender and flat leaves, whereas the Savoy types have very crinkled and thick leaves (Pritchard and Becker, 1989). Cabbage heads are generally compact and consist of many thick, overlapping leaves that are oval to circular in shape and surround the merismatic growing region (Pritchard and Becker 1989).

Cabbage is an economically important crop in Thailand and one of the most widely cultivated vegetables in Northern Thailand, particularly in Phetchabun province (Table 2.2). In addition, Phetchabun province also has the highest in yield of production due to the climate in this area is suitable for growing the cabbage in Thailand (DOAE, 2009).

Table 2.2 Cabbage production in Thailand.

Provinces	Planted area (rai)*	Yield (kg/rai)	Total (tons)
Phetchabun	14,253	5,125	79,027
Chiang Mai	13,179	2,753	38,988
Maehongsorn	9,810	2,795	22,804
Tak	3,727	4,405	16,080
Nan	2,717	3,977	5,954

Source: DOAE, 2009; *1 rai = 0.16 hectare

2.3.2 Cabbage head development

Presently, there is no standard terminology for describing cabbage growth stages like there is for rice. Although terms such as “head formation” and “cupping” do exist, it can be confusing because this terminology is often regional and can vary among farmers and others involved in agriculture. Accurate cabbage growth stage descriptions are particularly useful in pest management since plant susceptibility to cabbage pests varies with the growth stage. The growth stages below can be used to develop, with farmers, a more appropriate growth stage description or cropping calendar for a specific area, based on locally used classification (Andaloro et al., 1983).

2.3.2.1 Cabbage growth stage

Terminology describing crop growth stages of many commodities is often regional and can vary greatly among growers and others involved in agriculture. This lack of standardization can easily lead to misunderstandings and mistakes in crop management. To overcome this problem, the growth stages of such crops as corn, wheat, soybeans, and sugar beets have been described and given specific terms to which anyone involved in production can refer (Russell et al., 1981). Presently there is no standard terminology for describing cabbage growth stages. Although terminology such as “head formation” and “cupping” does exist, it can be ambiguous and confusing if not properly defined. More accurate descriptions and precise terminology of cabbage growth stages would be useful to those involved in cabbage production to standardize the timing of agronomic and pest control events relative to crop growth (Andaloro et al., 1983). The stage of growth and development of cabbage head is presented in Figure 2.3.

Stage 1: Cotyledons. Flea beetles are the most important problem during the cotyledon stage, causing small “shot” holes in the cotyledons and stems and sometimes cutting the stem. Besides cutworms, other insect pests are usually not present. Diseases such as black leg and black rot are very hard to detect at this stage and often go unnoticed.

Stage 2: Seedling. Flea beetle feeding may still be damaging. Cabbage maggot injury to the roots or hypocotyl region is likely to appear at this stage and/or later and could kill the young seedling. Diamondback moth and imported cabbage worm larvae can occasionally be found on plants at this stage depending on time of planting. Symptoms of black rot or black leg may show up in this or any succeeding growth stage. Seedlings with 5-6 true leaves would be adequate for transplanting, if growing conditions are ideal.

Stage 3: 6-8 true leaves. Flea beetle feeding becomes less important as the plants get larger. Cabbage maggots could still cause serious root injury. Larvae of the diamondback moth and imported cabbageworm may feed on the heart leaves and cause damage. Plants in this stage are better suited to withstand adverse growing conditions when transplanted than the smaller seedlings.

Stage 4: 9-12 true leaves. Flea beetle feeding damage is usually not harmful to the plant at this and succeeding stages. Maggot injury is less important as the roots become better established. Diamondback moth, imported cabbageworm, and cabbage looper (Lepidoptera) larvae may be present and could require control measures.

Stage 5: Precupping. At this and succeeding stages, cabbage maggots will only reduce yield if the infestation is severe or if plants are under drought stress. This stage is not susceptible to thrips injury, but during the early cupping stage thrips may become protected by the cabbage leaves if they are feeding in the heart leaves. Thus, control measures may need to be implemented at the end of the precupping stage to suppress developing thrips populations. Lepidopterous larval population densities may reach treatment thresholds.

Stage 6: Cupping. Thrips can become protected in the heart leaves starting at this stage, thus making topically applied insecticides with no systemic activity ineffective. Lepidoptera may reach treatment thresholds.

Stage 7: Early Head Formation. Thrips can reproduce and cause damage in the developing head. Lepidoptera may reach treatment thresholds. Wrapper leaves begin to appear and must be protected from foliage feeding insects, alternaria, downy mildew, and sclerotinia in storage and fresh market cabbage. Secondary black rot infection may occur and may warrant control in wet conditions.

Stage 8: Head Fill. Thrips can reproduce in the head where they are protected from insecticides. Storage and fresh market cabbage must be protected from foliage feeding insects as the wrapper leaves and head could be damaged; however, only severe infestations would affect the grade of processing cabbage. New infections of black rot may not affect the head but may cause spotting of the wrapper leaves. Storage and fresh market cabbage should be protected from the diseases alternaria, downy mildew, and sclerotinia. Tipburn and black petiole could result from unfavorable growing and nutritional conditions during this stage.

Stage 9: Mature. Storage and fresh market cabbage must be protected from alternaria, downy mildew, sclerotinia, and foliage feeding insects. Black rot symptoms are inconsequential to yield, but may affect the marketability of cabbage. Yield or grade of processing cabbage is affected only by a severe infestation of any pest.

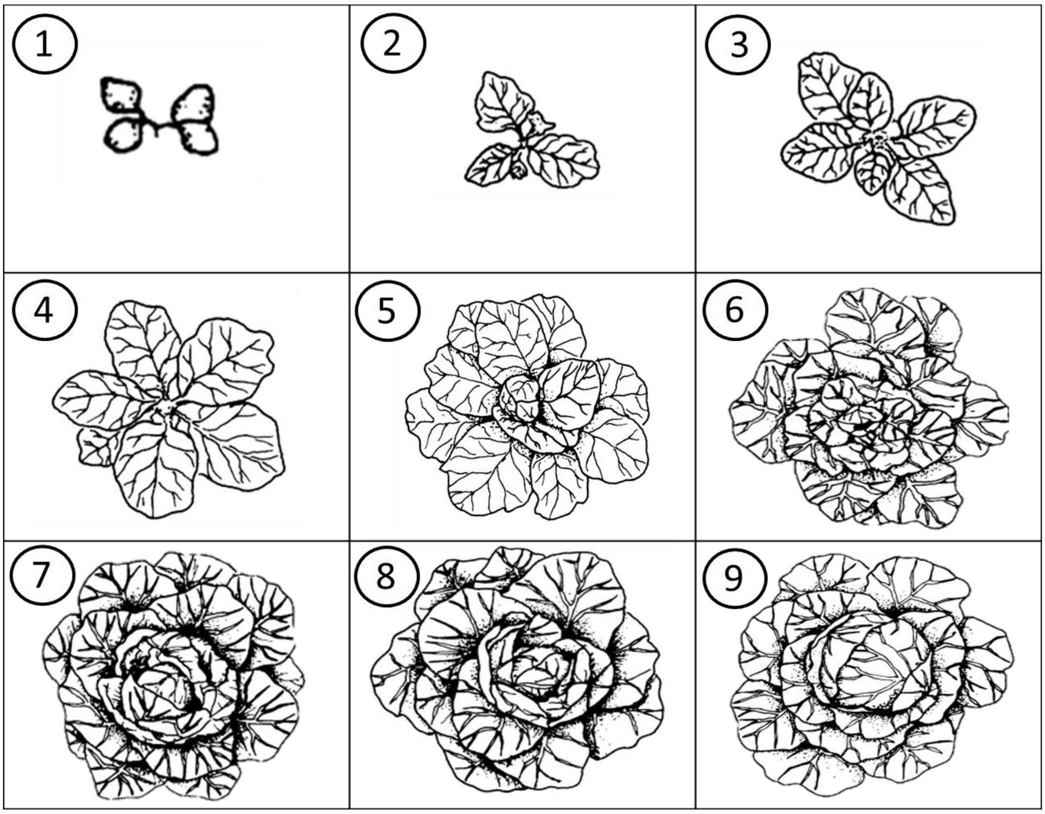

Figure 2.3 Cabbage growth stage (Andaloro et al., 1983).

2.3.3 Quality components of cabbage

Cabbage heads are generally compact and consist of many thick and overlapping leaves that are oval to circular in shape and surround the merismatic growing region (Pritchard and Becker 1989). Good quality cabbage should have firm or hard heads that are heavy for their size. The outer leaves should be of a bright green color, crisp and fresh, and free from blemishes (Figure 2.4). The leaves are considered fresh if they squeak when rubbed together (Boyette et al., 1999), and the presence of a waxy bloom on the leaves is also considered a good indication of freshness (Prange, 2004). The major signs of loss of quality are yellowing of the outer leaves, core elongation, internal yellowing in the apex region, leaf abscission, and sometimes rootlet development at the core-end (Cantwell and Suslow 2007). Separation of the petioles of the leaves from the central stem at the base of the head indicates senescence and loss of quality (Pritchard and Becker 1989). The bright dark green outer leaves of a cabbage are usually trimmed before sale, exposing the inner leaves that are usually a pale green color. For that reason, most of the cabbages available at the market have a light yellowish-green color. Previous reports have been studied in some points especially the quality aspect.

Figure 2.4 Good quality of cabbage head.

2.3.3.1 Nutritive values of cabbage

The main constituents of green cabbage are carbohydrates, comprising nearly 90% of the dry weight, where approximately one-third is dietary fiber and two-thirds is low molecular weight carbohydrates (Wennberg et al., 2006). Freshly harvested cabbage contains on average 90.6-92.5% water, 1.2% protein, 0.12-0.18% lipids, 5.4% carbohydrates, and 1.6-6.2% fiber (USDA, 2006; Wennberg et al., 2006). Total sugar content varies depending on the cabbage cultivar from about 3-9%. Glucose (1.40-2.06%) is the most important sugar, followed by fructose (1.06-1.74%) and sucrose (0.02-0.05%) (Pritchard and Becker, 1989; USDA, 2006; Wennberg et al., 2006). The predominant fatty acids in the total lipid analyses of cabbage are linolenic, linoleic, oleic, palmitic, and stearic acids (Peng, 1982). Cabbage has long been recognized as an important source of ascorbic acid (vitamin C), containing from about 5.7-83 mg/10 g fresh weight (Proteggente et al., 2002; Singh et al., 2006; USDA, 2006; Podsedek, 2007). The pointed-head cultivars usually contain more ascorbic acid than other cabbage cultivars, with the early maturing types generally having higher levels than the late mature types. The highest levels of ascorbic acid are found in the outer green leaves and in the edible portion of the core. Cabbage is also very rich in S-methylmethionine (up to 20.7 mg/100 g fresh weight), a derivative of methionine, also known as vitamin U or the antiulcer factor. Vitamin U is enzymatically or non-enzymatically broken down into homoserine and dimethylsulfide. Volatile dimethylsulfi de is one of the quality components of cabbage (Howard and Russell, 1997; Takigawa and Ishii, 2000).

Vitamin A content is relatively low in cabbage (126 IU/100 g fresh weight), with the highest levels found in the outer green leaves due to the higher carotenoid concentration, while mature heads contain less vitamin A than immature heads (USDA, 2006).

The β-carotene content of different cabbage cultivars ranged from 0.009 to 0.41 mg/100 g fresh weight, while lutein content ranged from 0.021 to 0.45 mg/100 g fresh weight (Singh et al., 2006; Podsedek, 2007). Vitamin E (DL-α-tocopherol) in different cabbage cultivars ranged from 0.030 to 0.509 mg/100 g fresh weight (Singh et al., 2006).

Cabbage is also rich in total phenolic compounds (12.58-203 mg/100 g fresh weight), particularly hydroxycinnamic conjugates (37.9-50.4 mg/100 g fresh weight) and kaempferol (12.8-17.2 mg/100 g fresh weight), which confer a good antioxidant capacity (Ferreres et al., 2006; Heimler et al., 2006; Melo et al., 2006; Podsedek, 2007). There is, however, a large variation in the antioxidant phytochemical contents among cabbage cultivars. Higher vitamin C, vitamin E, and phenolic contents were found in red cabbage, higher β-carotene was found in Savoy cabbage, while higher lutein content was found in white cabbage (Singh et al., 2006). Phenolic compounds together with vitamin C constitute the major antioxidants in cabbage, due to their high content and high antioxidant activity, while carotenoids and vitamin E are only responsible for 20% of the total antioxidant activity in cabbage (Podsedek, 2007).

Other characteristic components of cabbage are glucosinolates, which are sulphur-containing glycosides. The sharp, biting, and pungent taste of cabbage has been attributed to the breakdown products of glucosinolates, and these compounds are believed to have a protective effect against cancer (Verhoeven et al., 1977). Green cabbage cultivars may contain between 1, 280 and 1, 457 μg of glucosinolates per 100 g dry weight (Wennberg et al., 2006; Song and Thornalley, 2007).

2.3.3.2 Cultivar

Four cultivars of cabbage have been grown for commercial production including Chang No. 4, T-523, T-530 and T-593. All cultivars are imported from Japan and the main cultivars grown for domestic markets in Thailand. Each cultivar has different advantages. Chang No. 4 had a very strong tolerance to rain and was very strong in transporting long distances. This cultivar was the most suitable for long distance transport. Cabbage cultivars T-523, T-530 and T-593 had better tastes than that of Chang No. 4; however, these cultivars had the limitation of being sensitive to physical damage.

Table 2.3 Details of cabbage cultivars used in commercial farms in Thailand.

Cultivar	Source of collection	Imported company	Optimum growing temperature	Main Characters
Chang No. 4	Japan	Seng Heng Huat Seed Co., Ltd	15-20 °C	-big head and firm -very strong tolerance to rain -very strong tolerance to long distance transport
T-523	Japan	Chia Tai Seed Co., Ltd	20-45 °C	-high growth rate -disease resistance - tolerance to rain - tolerance to transporting -good eating quality -market needs -(1.5-1.8 kg/head)
T-530	Japan	Chia Tai Seed Co., Ltd	20-45 °C	-rapid head formation -highly productive -disease resistance - tolerance to rain - tolerance to transporting -good eating quality -market needs - (1.5-1.8 kg/head)
T593	Japan	Chia Tai Seed Co., Ltd	20-45 °C	-good head formation -compact head size - tolerance to heat -high stem -able to adapt to different climate conditions

2.3.4 Quality management for cabbage

2.3.4.1 Good agricultural practices (GAP)

2.3.4.1.1 Importance of GAP

Over the past two to three decades there has been an increase in food borne illnesses associated with the consumption of fresh fruits and vegetables (fresh produce). Most of these outbreaks were associated with microbial contamination. The major microbes that have been implicated include *Salmonella*, *Escherichia coli* 0157:H7, *Campylobacter*, *Listeria monocytogenes* and the *Norwalk* virus. Protozoan type organisms (*Cryptosporidium sp*.) were also implicated in some outbreaks. Nematodes (*Strongylus sp*.) have also been a source of food borne illness. Traceback studies subsequently indicated that in most cases, breaches occurred during production and postharvest handling, which leads to contamination and illness. In an attempt to reduce these risks, GAP Protocols were developed. In 1991, the United States Department of Agriculture (USDA) introduced the first voluntary guidelines whose primary objective was to reduce the microbial population of fresh produce. A European model, referred to as EurepGAP, the precursor of Global GAP, was subsequently introduced. The European model, while placing emphasis on microbial reduction, also places great emphasis on integrated pest management and pesticide usage. When first developed, GAP was suggested as a voluntary guideline. With the passage of time these guidelines have started to become more enforceable. In fact, in the U.S., more companies that distribute fresh produce are demanding mandatory third party independent audits of fresh produce growers as a prerequisite for purchasing. In January 2006, the European Union (EU) implemented its pesticide initiative program. This measure will have tremendous implications for Caribbean exporters whose products are marketed in the European Union. In addition, the International Standardization Organization (ISO) is in the process of finalizing an international food safety standard ISO 22000:2005. When it was finalized in December 2005, GAP and EurepGAP was made mandatory as the Prerequisite Program (PRP) for all suppliers and inputs entering food establishments that wish to become certified. The protocols presented in this document combine aspects of both the American model and EurepGAP.

2.3.4.1.2 GAP Adoption in Thailand

Thailand declared 2004 the “year of food safety” as part of a national strategy on food production, called the “the kitchen of the world” strategy. This strategy included a “Road Map of Food Safety”, which provided for the safety of agricultural inputs, production at farm level, control of crop protection products and quality crop production. Certification of GAP ensures these key elements of safety and reduces the burden of government inspection. Farmers who fulfill the requirements of the national GAP program can label their products with the GAP logo. In addition, a regional GAP program in the western part of Thailand (known as the Western GAP cluster) has developed Thai GAP standards based on Global GAP Standards.

The Department of Agriculture has set up a national GAP system for agricultural production and is responsible for control and inspection. National GAP standards have also been developed for livestock and fisheries. Farmers who apply for GAP certification are assessed for production processes (especially the appropriate use of agrochemicals). The standard contains eight elements:

1. Safety of water used
2. Site safety and sanitation
3. Use of agrochemicals
4. Product storage
5. Data records
6. Pest-free products
7. Quality management
8. Harvesting and post harvesting handling

The standards also ensure that all stages of production, processing and marketing are subject to inspection and all records are available. The objectives of the GAP program are to ensure that food crops produced in Thailand are safe, wholesome and meet high standards while ensuring the safety of growers and minimizing adverse impacts on the environment. By May 2008, nearly half of Thailand’s 363,946 registered farms were certified for GAP standards, specializing in fruit vegetables, swine, poultry, cattle and aquaculture.

2.3.4.1.3 The case of western Thailand GAP for fresh vegetables

Thailand is one of the world's leading exporters of high value fresh vegetables, providing 85 percent of the world market in baby corn and serving as the world's 7th leading exporter of asparagus. These exports faced increasingly stringent food safety and quality requirements from foreign markets, which caused difficulties for exporters. Problems with toxic residues were a particular challenge. A cluster of small-scale vegetable farmers, vegetable processors, exporters, government agencies and university agricultural experts worked together to analyze the problem. Under a "cluster development" development program funded by USAID, supported by TICA and managed by the Kenan Institute Asia as part of the Thailand Competitiveness Initiative, the project cluster decided to use the GAP standard, as it was the most effective way to eliminate residues without the expense and delays of government inspection of export shipments.

The cluster, which included Kasetsart University, Thailand's leading agricultural university, helped establish the Thai GAP based on GLOBALGAP. University experts worked with the Ministry of Agriculture and Cooperatives and the Ministry of Commerce to develop training materials in Thai and establish a training program that reached tens of thousands of Thai farmers. The cluster cooperated with European supermarket chains who are the biggest purchasers of Thai fresh vegetables to review the standards.

From this beginning in one region of the country, the use of GAP standards has expanded nationwide under the Ministries of Agriculture and Commerce, with the private sector remaining an influential partner in the certification. The Thai GAP standard is now overseen by the Thai Chamber of Commerce and the Board of Trade of Thailand. Certification provides permission for products to have a Q (for quality) logo on their packaging. The Q mark is a legally registered certification mark that provides assurance that the produce is of high quality and is safe for consumers. A 20 digit code appears below the Q mark to enable the produce to be traced back to a particular farm.

2.3.4.1.4 GAP for cabbage

It is widely accepted that the quality of vegetable begins at the farm gate, but such quality depends on the production conditions. The Department of Agriculture (DOA) of Thailand sets GAP guidelines for cabbage. The GAP system sets a production plan to control production processes to obtain standard quality and safety of produce to consumers. DOA transfers the GAP technologies to growers (Appendix 5). The GAP guideline has been applied for cabbage in order to manage the quality of cabbage from the farm as well as for the postharvest quality of cabbage.

2.3.4.2 Postharvest quality management of cabbage

2.3.4.2.1 Optimum postharvest handling conditions

Cabbage should be pre-cooled as soon as possible after harvest to reduce wilting. Hydro-cooling before storage or forced-air cooling can be used to remove field heat (Boyette et al., 1999). A temperature of 0 °C with a 98-100% relative humidity is recommended for long-term storage of cabbage in order to reduce moisture loss and yellowing (Prange, 2004). The maximum storage life and retention of cabbage quality varies greatly depending on the cabbage type, cultivar, and storage conditions. Early cabbage is generally stored for short periods of 3-6 weeks, while late cultivars can maintain their quality for 6-7 months (Cantwell and Suslow, 2007). Storage under light may reduce physiological disorders such as leaf yellowing and weight loss (Prange and Lidster, 1991), while exposure to ethylene may reduce cabbage quality due to enhanced yellowing and accelerated senescence (Prange, 2004).

2.3.4.2.2 Effects of temperature on quality

a) Disease and yellowing development

Bacterial soft rot, yellowing, and discoloration were reported to be the major causes of cabbage deterioration in shipments arriving to the New York market from different locations worldwide. Bacterial soft rot affected 60% of the cabbage shipment, followed by yellowing and black discoloration, which affected on average 16 and 14% of the shipments, respectively (Ceponis et al., 1987). Core elongation was also observed in stored cabbage. After 15 weeks of storage at 0-1°C, core elongation started to be evident, and after 6 months stalks emerged from most of the cabbage heads (Guffy and Hicks, 1984). The loss of green color was also rapid when cabbage was stored at temperatures >0 °C (Parsons et al., 1960). The color of cabbage stored at 0 °C shifted from a dark dull green toward a light (higher L*), brighter (higher saturation), and more yellow hue during storage. Chlorophyll content and color intensity also declined as trim loss increased, due to the removal of greener outer leaves (Prange and Lidster, 1991).

b) Weight loss

Weight loss of cabbage increases during the postharvest period, as storage time and temperature increase (Sundstrom and Story, 1984). For example, weight loss in cabbage stored at 0°C increased from 5.6% after 3 months to 9.5% after 6 months (Prange and Lidster, 1991). After 6 months, weight loss of cabbage stored at 0-1°C attained 3.9-5.7% of the initial weight, depending on the cultivar and season of harvest (Nilsson, 1993). Weight loss of Chinese cabbage also increased during storage, attaining 2.1% after 9 weeks of storage at 2 °C (Porter et al., 2004). Cabbage stored in a domestic refrigerator with temperatures ranging from 4 to 8 °C lost about 3% of the initial weight after 7 days, while maximum weight loss in cabbage stored at ambient temperature (12-22 °C) was 9.6% of the initial weight. After 7 days, cabbage stored at ambient temperature was visibly decayed and dry (Song and Thornalley, 2007). Weight loss of cabbage increased with the length of storage period and ranged from 5.0% of the initial weight after 3 or 4 weeks at 0 °C to 13.7% after 7-8 weeks at 7 °C. This weight loss corresponded to a moderate to severe wilting, respectively (Parsons et al., 1960). When weight loss exceeded 5% of the initial weight loss, cabbage showed visible wilting, while maximum weight loss before cabbage became unacceptable for sale ranging from 7 to 10%, depending on the cultivar (Robinson et al., 1975).

Weight reduction during storage of cabbage is not only attributed to loss of moisture due to transpiration but also to trimming of damaged external leaves. Regular trimming of senescing leaves from cabbage heads during storage results not only in loss of the typical bright green cabbage color but also in loss of profit as it produces a lower marketable head weight and significantly higher labor cost. However, trimming of cabbage during storage seems to be inevitable and losses of up to 20% during long-term storage can be expected due to moisture loss, leaf discoloration, and decay (Pritchard and Becker, 1989). Trimming losses increased with storage time and temperature, and after 7-8 weeks overall losses due to decayed, broken, or discolored leaves that had to be removed ranged from 8.1 to 13.4% in cabbage stored at 0 °C, from 8.2 to 18.6% in cabbage stored at 4 °C, and from 13.8 to 31.6% in cabbage stored at 7 °C (Parsons et al., 1960). In cabbage stored at 0 °C, trim losses ranged from 15.8 to 19.5% after 3 months, and from 22.3 to 22.6% after 6 months, depending on the cultivar (Prange and Lidster, 1991). Likewise, in Chinese cabbage, trimming losses increased from 16.2% to about 25% after 9 weeks at 0 °C (Klieber et al., 2002), while trimming losses in cabbage stored at 2 °C attained a maximum of 42.7% after 9 weeks (Porter et al., 2004).

High-humidity storage or plastic film wrapping have been successfully used to protect cabbage from loss of moisture during prolonged storage. The use of perforated or nonperforated polyethylene crate liners reduced the weight loss of stored cabbage to less than 1% after 7-8 weeks at 0 or 7 °C. Cabbage green color was retained for longer periods, and losses due to discoloration, wilting, and decay were usually less in polyethylene-lined than in unlined crates (Parsons et al., 1960). Storage of cabbage at 98-100% relative humidity reduced decay, moisture loss, and color loss, compared to storage at 90-95% relative humidity, regardless of the temperature. After 30 days, weight loss of cabbage stored at 90-95% relative humidity attained 1.6, 2.2, and 2.6% in cabbage stored at 0-1 °C, 3.5-4.5 °C, and 7-8 °C, respectively. On the other hand, weight loss of cabbage stored at 98-100% relative humidity attained 0.5, 0.7, and 1.4% after 30 days under the same temperature conditions. Consequently, cabbage stored at higher humidity remained firm and crisp and retained its green color longer. Storage life of cabbage stored at 3.5-4.5 °C was limited to 4-5 months, while storage life of cabbage stored at 7-8 °C was reduced to 2-3 months due to internal growth and rooting. At 0-1°C there was little rooting and internal growth after 7 months (Van den Berg and Lentz, 1973).

Compositional changes were also observed during prolonged storage of cabbage. For example, fructose and glucose contents decreased during storage of cabbage for 6 months at 0-1°C, while sucrose and soluble solids content decreased from the time of harvest until 4 months of storage, increasing afterward to a level comparable to that at the time of harvest (Nilsson, 1993).

c) Ascorbic acid content

Ascorbic acid content may be reduced from 51 to 42 mg/100 g fresh weight during storage of cabbage (USDA, 2006). One day after harvest ascorbic acid content of cabbage was reduced by approximately 22% (Vanderslice et al., 1990). However, others have shown ascorbic acid retention of 95% in green cabbage stored for 3 weeks at 2 °C and 95-100% relative humidity, while sulfur content increased from an initial value of 66.04 mg/100 g to 70.40 mg/100 g fresh weight under the same storage conditions. The same authors concluded that sulfur-containing compounds found in cabbage might be involved in ascorbic acid retention (Albrecht et al., 1990).

2.3.4.2.3 Effect of impact damage on cabbage head quality

Cabbages are generally harvested by hand in order to avoid mechanical damage from machine harvesting. After harvesting, they are packed and transported to marketplaces or are placed into bulk containers and stored in cold storage for further packing and distribution. During handling and distribution, loss of quality and yield caused by impact stress is likely due to improper postharvest handling and management of bulk storage and transportation quality (Thammawong et al., 2011).

A study of the effect of mechanical stress in cabbage on the cracking of leaf layers has been conducted. However, little information is known about the stress response mechanism in cabbage, and there are few reports investigating the effect of mechanical stresses (impact, compression, and vibration) on the physiological and biochemical changes in cabbage heads, either directly after receiving stress or during long-term storage (Thammawong et al., 2011).

The harvested cabbages were treated with different degrees of impact by letting the cabbage head fall from the heights of 80 cm, 40 cm, 20 cm, and 10 cm. Each individual cabbage head was dropped 3 times from the same height onto a flat, rigid concrete floor, with the cut end (core) of the cabbage facing up (Figure 2.5 and 2.6).

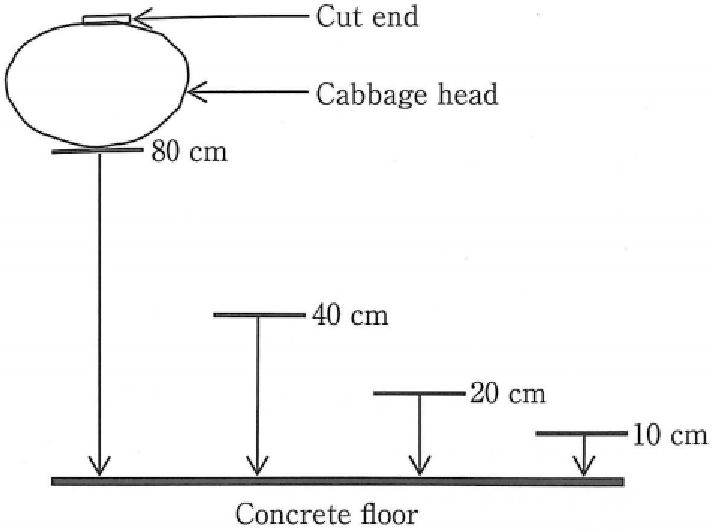

Figure 2.5 Schematic illustration of dropping treatment of cabbage at 80, 40, 20, and10 cm (Thammawong et al., 2011).

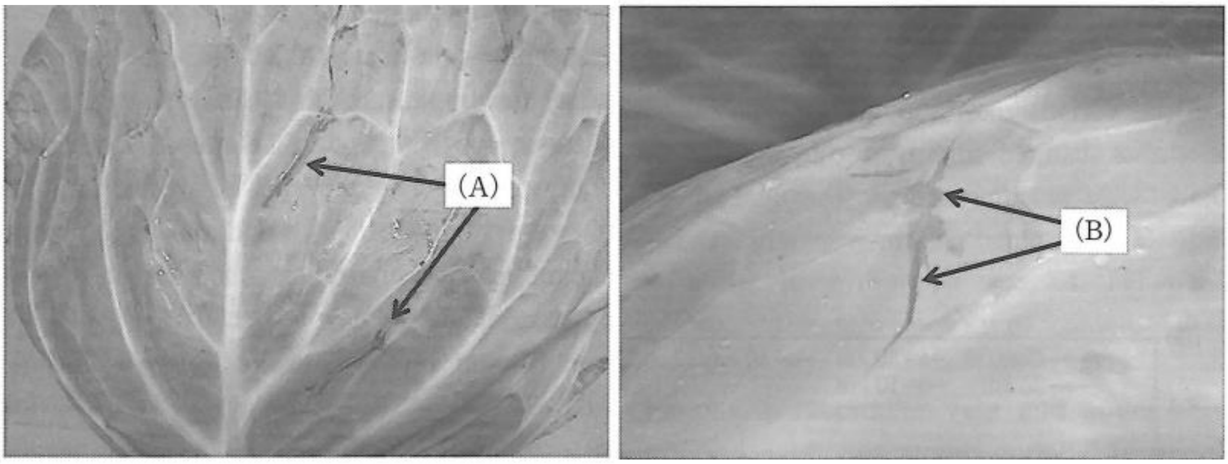

Figure 2.6 Injuries caused by dropping treatment from the height of 80 cm: the first layer (A) and the fourth layer (B) of the head leaf pack of cabbage (Thammawong et al., 2011).

The major effects of impact stress on cabbage heads include increases in the respiration rate and a loss of sugar content. In addition, tests of controlled atmosphere (CA) treatment on dropped cabbages showed that CA likely inhibited the severe damage caused by impact stress on cabbages because it reduced the rise in respiration rate and slowed the loss of sugar content in dropped cabbages during storage at 20 °C.

Overall, impact stress obviously affects the postharvest physicochemical properties of cabbage just after impact occurrence (respiration rate) and during storage (sugar content). These changes are also influenced by the strength of the stress level (height of dropping treatment) and the time period after the application of the stress treatment. Rapid and appropriate postharvest handling and storage management, therefore, will delay the onset of deterioration of cabbage quality and extend its shelf life (Thammawong et al., 2011).

2.3.5 Grade and Standard for Cabbage

2.3.5.1 Royal Project (Thailand) Standards for Grades of Cabbage

2.3.5.1.1 Cabbage

Figure 2.7 Grades and standards for cabbage under Royal Project.

Harvesting: 60-70 days after transplanting, and head compactness

Cultural practices: 1) Harvesting at suitable maturity stage
2) At least 3 wrapper leaves is covering the head
3) Pack cabbage head into the plastic basket with paper at the bottom

Quality requirements: Minimum quality of cabbage consists of heads of cabbage of one variety or similar varietal characteristics, which are of reasonable solidity and are free from damage caused by discoloration, disease, insects or mechanical or other means and have 2-3 wrapper leaves remaining (Figure 2.7).

Grade 1: 1) 0.7-1.5 kg net head weight as per requirements
2) Compact and firm head
3) Quality requirement: at least minimum quality requirement

Grade 2: 1) 0.5-0.7 kg net head weight as per requirements
2) Quality requirement: at least minimum quality requirement

Grade U: 1) <0.5 kg or > 1.5 kg net head weight
2) Defects must not exceed 10% of consignment

Arrangement requirements: Same variety should be packed in the same package for uniformity of quality

Storage: Stored at 0 °C, 98-100% RH for 3-6 week of storage

2.3.6 Problems in the Cabbage Supply Chain

The marketing of cabbage was carried out in a traditional and conventional way in terms of its organization, structure and distribution. The marketing channel involved a number of market intermediaries that resulted in high marketing costs. The producers were 'isolated' from the 'market centers' due to the lack of information exchanges. Hence, the producers were not producing enough to fulfil the market demand. Consequently, cabbage farm produce suffered from problems of low quality and inconsistent supply. Poor market infrastructures also aggravated their problems (Chanthasombath, 2011).

At present, the food retail industry has been growing rapidly in parallel to changes in the developed economy. This development was brought by globalization in particular to the free flow of capital between countries. This development, however, poses a challenge to the traditional distribution network. Recently, there has been an emergence of modern retail stores in the fresh fruit and vegetable sectors, namely supermarkets and hypermarkets that are continuing to rise in numbers, especially in major urban cities. In order to protect the small retailers, the Thai government has recently introduced new guidelines on the opening of new hypermarkets in an attempt to slow down their rapid growth.

Under the traditional system, the grower's produce has to go through a number of intermediaries before it reaches the consumers. In the case of marketing through hypermarkets, growers could either sell their produce directly to or through the processors who then sell it to the hypermarkets; hence shortening the distribution channel. Under the traditional system, on the other hand, the price is generally determined through 'personal negotiation' while the sale to the hypermarkets is normally formalized in the form of a contract; hence the price is set by the suppliers and the hypermarkets. Supermarkets and hypermarkets are expected to perform strongly in the future. It is very unlikely that independent grocery stores will be able to bridge the pricing advantage and provide a convenient and comfortable shopping environment as offered by these two types of outlets. Under such a scenario, a comparative study of the traditional and the new marketing structure will be able to provide some insights to 'the marketing gap and problems' faced by growers in keeping up with changes. The problems envisaged include poor farm level marketing practices, inefficient flow of information across market levels and price discovery mechanisms, high transportation costs, and inefficient postharvest practices for cabbage among others. All the information obtained is valuable in assessing the growers' readiness to integrate with the new marketing structure in order to improve the supply chain management system of cabbage in Thailand.

2.4 Supply Chain Management (SCM)

2.4.1 Definitions

The term 'Supply Chain Management' is relatively new. It first appeared in logistics literature in 1982 as an inventory management approach with an emphasis on the supply of raw materials (Oliver and Webber, 1982). Oliver and Webber discuss four characteristics of SCM:

1. SCM views the supply chain as a single entity. Therefore, it does not delegate fragmented responsibility for various segments in the supply chain to functional areas such as purchasing, manufacturing, distribution and sales.
2. Supply is a shared objective of practically every function in the chain. It is of particular strategic significance because of its impact on overall costs and market share.
3. SCM provides a different perspective on inventories, which are used as a balancing mechanism of last, not first, resort.

4. SCM requires a new approach to systems: integration, not simply interface, is the key.

Houlihan (1985) and Jones and Riley (1985) elaborate on the concept emphasizing a reduction in inventory both within and across firms. Jones and Riley (1985) claim that SCM should fulfil final customer service requirements, define where to position inventories along the supply chain and how much to stock at each point, and it should develop appropriate policies and procedures for managing a supply chain as a single entity. Lee and Billington (1992) state that supply chain analysis is much more than just inventory modelling. It can be extended to distribution strategy analysis and to other types of SC problems (Lee and Billington, 1995).

Around 1990, academics first described SCM from a theoretical standpoint to clarify how it differed from more traditional approaches to managing the flow of materials and the associated flow of information (Ellram and Cooper, 1990). Initially, according to Bechtel and Jayaram (1997), the emphasis was on facilitating product movement and coordinating supply and demand between a supplier and buyer. Logistics managers in retail, grocery, and other high inventory industries began to see that a significant competitive advantage could be derived through the management of materials through inbound and outbound channels. Purchasing literature states that SCM evolved from an upgrade of the purchasing function to an integral part of the corporate planning process. Since its introduction in the retail industry, the supply chain concept has spread to other industries such as computers and copiers. Other terms are also used for SCM activities:

- Tan et al. (1998) refer to comparable labels used in purchasing literature, including integrated purchasing, supplier integration, buyer-supplier partnerships, supply base management, and strategic supplier alliances.
- Womack and Jones (1994) refer to the lean enterprise as a group of individuals, functions, and legally separate but operationally synchronized companies.
- Lambert and Stock (1993) introduced the concept of Integrated Channel Management, and described it as ‘the coordination of all activities, beyond just the traditional logistics activities, between channel members that result in a high level of customer satisfaction for end-users’.

- The concept of Demand Chain Management (Christopher, 1998) has also been proposed to distinguish it from the type of management in which 'supply' begins and drives the chain of activities.

While at the beginning SCM was mainly discussed in purchasing literature (see the labels for SCM presented by Tan et al. (1998), the emphasis now lies on the process of supplying goods to consumers to fulfil their needs. Comparable initiatives have been undertaken at the industry level. Various concepts have been presented, such as the extended enterprise, which is characterized by a dominating company who extends its view and scope of operation, takes the lead and sets the pace. The virtual enterprise is characterized by complementary contributions from a number of different companies, where one company plays the role of a broker (Hayfron et al., 1998). From a marketing perspective, Stern et al. (1996) define a marketing channel as 'an orchestrated network of interdependent organizations that creates value for end-customers by generating form, possession, time and place utilities'. However, Johnson and Wood (1996) view the supply chain as an extension of the marketing (or distribution) channel. First of all, suppliers of the manufacturer are included. Furthermore, supply chains consider the re-engineering of products and processes and place particular emphasis on inventory management, communication and coordination issues. Whilst supply chains aim at long-term agreements between parties, a marketing channel functions with daily market transactions.

Ellram and Cooper (1993) state that SCM is an approach whereby the entire network, from suppliers through to the ultimate customers, is analyzed and managed in order to achieve the 'best' outcome for the whole system. It includes analyzing the level and location of supply chain inventories, managing information flows throughout the channel, and coordinating efforts to best meet the customer's needs.

2.4.2 Supply Chain operations Reference (SCOR) Model

The SCOR model is a business process reference model that provides a framework that includes SC business processes, metrics, best practices, and technology features (Theeranuphattana and Tang, 2008). According to Robinson and Malhotra (2005), SCOR model defines a supply chain as an integrated processes of ‘plan’, ‘source’, ‘make’ and ‘deliver’ and ‘return’ that span the value chain from the supplier’s supplier upstream to the customer’s customer downstream. SCOR-model provides a unique framework that links business process, metrics, best practices and technology features into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chain management and related supply chain improvement activities (Supply Chain Council, 2007). The definitions of the five SCOR supply chain processes are presented in Table 2.3.

Table 2.4 Definitions of SCOR processes.

SCOR Process	Definitions
Plan	Plan processes that balance aggregate demand and supply to develop a course of action that best meets sourcing, production and delivery requirements
Source	Processes that procure goods and services to meet planned or actual demand
Make	Processes that transform product to a finished state to meet planned or actual demand
Deliver	Processes that provide finished goods and services to meet planned or actual demand, typically including order management, transportation management, and distribution management
Return	Processes associated with returning or receiving returned products for any reason. These processes extend into post-delivery customer support

Source: (Huang et al., 2005)

One of the views of the SCOR model is that a supply chain must be measured and described in multiple dimensions. These dimensions include reliability, responsiveness, flexibility, cost, and efficiency of asset utilization (Van der Vorst, 2006). The advantages of the SCOR model are that it takes into account the performance of the overall supply chain, it proposes a balanced approach by describing performance of supply chain in multiple dimensions. Van der Vorst, (2006) described the four key performance indicators within SCOR as: reliability measures (fill rate, perfect order fulfilment), cost measures (cost of goods sold), responsive measures (order fulfilment lead-time), and asset measures (inventories).

The SCOR model demonstrates that only a single weak link in the supply chain can result in detrimental performance such as late deliveries, incomplete order fulfilment, or poor product quality. This shows that integration of quality activities and logistics activities is important in the supply chain as sub-standard operations in either quality control or logistics control can result in incidence of fruit defects. The SCOR model presented is relevant to this study as it helps to understand different processes and respective decisions that can be made at these stages in the supply chain. The literature is reliable and valid as the SCOR model is used in practice by many companies and also the selected literature was published in scientific articles (Van der Vorst, 2006).

2.4.3 Case Studies of Vegetable Supply Chain in Different Countries

2.4.3.1. Vegetable supply chain in Shanghai, China

The leafy vegetable supply chain in Shanghai province, China is shown in Figure 2.8.

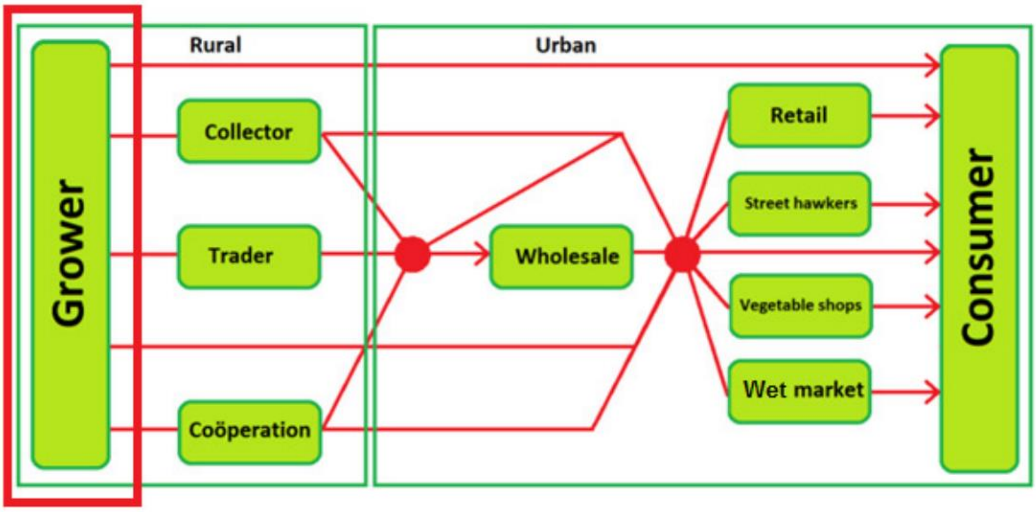

Figure 2.8 The leafy vegetable supply chain in Shanghai, China (Voskamp, 2013).

The leafy vegetable supply chain in Shanghai province is divided in different ways from grower to consumer. The supply chain of leafy vegetables is described.

Grower

The fragmentation of the farmers is a big concern of retailers and the government. Because of this the government wants to decrease the number of farms. To achieve this they support farmers with money to cooperate, but so far only entrepreneurial farmers gather other farmers around them to receive money from the government. The small family owned farms sell their vegetables at the wholesale markets. They are too small to produce for the large retailers. But when the farmers are bigger and are able supply quantity to, for example, a fast food chain, the management is well organized, but there is still a lack of employees who really know how to grow the different kinds of crops. The international cooperation between Rijk Zwaan, Chiquita and Metro is one of the success stories of what cooperation can bring in China. They managed together the process from farm to consumers and achieve goals when it comes to quality and quantity (Voskamp, 2013).

Wholesale market

The different wholesale markets in Shanghai are closely monitored by the Chinese government to make sure there are enough vegetables available for the citizens of Shanghai. The wholesale markets are the only place in Shanghai where the suppliers of vegetables from Shanghai province and other province bring their products to. However, future wholesalers have to think of ways to be distinct. If they can bring a wide of range of products together and create an efficient logistic chain, retailers will be eager. This is because without cool storage, the shelf life of vegetables and especially leafy vegetables deteriorates rapidly (Voskamp, 2013).

Retailer

Even though Shanghai has the most developed retail system in China, the retailer cannot purchase the vegetables directly from the source. In 2013 retailers were still not able to purchase in an efficient way, which has great consequences for the quality and shelf life of the products. Nowadays, when a retailer can buy directly from the source, it costs a lot of effort and time to achieve an efficient purchase system. Retailers try to get customers to be loyal to their stores. Carrefour and Metro try to achieve this by providing customers with good quality leafy vegetables, but also with, for example, track and trace systems (Voskamp, 2013).

Wet market

In recent years the government tried to upgrade the wet markets to modern markets, but they did not succeed. Despite the increasing wages of the people in Shanghai, they still prefer the wet market to buy vegetables. Cultural preference is that many Shanghainese consumers prefer the purchase of fresh leafy vegetables on a daily basis. They buy leafy vegetables every day in small quantities without using a refrigerator. Also, the price can be lower than at the supermarket. This makes the difference in purchasing vegetables at the wet markets (Voskamp, 2013).

Consumer

Consumers in Shanghai can choose every day where to buy their leafy vegetables. The location where to buy the vegetables depends on the disposable income. Consumers are aware of the importance of healthy food and they buy leafy vegetables, if they can afford it, in shops where the price may be higher, but they expect a better product. The demand of vegetables in Shanghai province will continue to rise through the year of 2020. There will then be a lot more consumers and the average amount spent on (leafy) vegetables will rise. Despite the 33% of population being elderly people, consumers will become more modern because of influences from abroad. This will change the demand of vegetables and leafy vegetables. Consumers will ask for more kinds of vegetables than they do nowadays.

Strong and weak points of farmers in Shanghai province, China

<u>Strong points</u>

- Shanghai province has enough area to be self-sufficient.
- Farms that produce lettuce for the fast food companies and have implemented a HACCP protocol to control the processes.
- Marketing of organic farms.

Weak points

- Fragmentation of the farms
- No cooperation between the huge number of farmers
- Knowledge level of the farmers is low
- Entrepreneurial mind set of the farmers

What does the consumer in Shanghai look like in 2020?

In 2020 the consumer in Shanghai will be different than the consumer is now in 2013. A large number will be the mainstream or even affluent people. Their spending pattern is changing rapidly, and their demand of leafy vegetables is also changing. It is hard to say if all of the consumers, even when they earn enough money, will buy their leafy vegetables at the supermarket or not. Even when they prefer brands and are concerned about the quality of their vegetables they still will buy vegetables at the wet markets. This is especially true of the elderly people, because they are used to buying their vegetables here (Voskamp, 2013).

What are logistic flows between the different players in the leafy vegetable supply chain?

The logistic flows from farmer to consumer differ in many ways. There are a couple of logistic ways the products can go. To start at the farmer, some of the farmers sell directly to the consumer using a web shop. But this concerns only a small number of (organic) farmers. Also, a small number of farmers and mainly the larger farms sell leafy vegetables directly to retail. Because of fragmentation of the farmers, 2.7 million in Shanghai, most of the farmers bring their products to one of the wholesale markets in Shanghai. Sometimes transport is organized by one of the bigger farms, or they sell the products to middle men (Voskamp, 2013).

What kinds of cooperation in vertical and horizontal ways are there in the leafy vegetable supply chain?

There is almost no cooperation in horizontal or vertical ways in the leafy vegetable supply chain. When farmers cooperate it is mainly because of the financial support of the government. The cooperation that was found during this research is between Metro, Rijk Zwaan and Chiquita. Other vertical or horizontal cooperation in the supply chain have not been found during the research (Voskamp, 2013).

What are the bottlenecks in the leafy vegetable supply chain?

There are a few bottlenecks in the supply chain of the leafy vegetables. First of all, the lack of cooled transport and storage is dramatic for the shelf life of the leafy vegetables. Without cooled storage or transport the quality of the leafy vegetables during transport and warehousing decreases rapidly. Secondly, farmers are unaware of the changing consumers' demand of leafy vegetables, and retailers want to respond to the changing consumer demand but cannot purchase the demanded leafy vegetables in an efficient way. Because the retailers want to exclude wholesale market of their procurement process, the future for wholesale markets in Shanghai uncertain (Voskamp, 2013).

What are the factors of success in the leafy vegetable supply chain?

At first one of the success stories in China is the cooperation of the breeding company Rijk Zwaan with Chiquita and the retailer Metro. They created a closed supply chain where lettuce is sold to the consumer in Shanghai. They work closely together and are focused on the demand of the consumer. The success of this cooperation is because of the marketing effort to stimulate consumers in Shanghai to buy lettuce. Besides the cooperation of these international companies, the national state owned company Bright Food Group is also doing a great job. They are focused on a farm-to-table chain. They manage large agriculture companies and processing industries and have their own supermarket chain. In these closed chains it is easier to maintain the quality of the vegetables (Voskamp, 2013).

Is the current leafy vegetable supply chain in Shanghai province prepared for the year 2020?

For 2020 there will be a lot of expectations from the consumer, their way of living and changes in consumption. The supply chain is just not ready for a consumer that is going to change their demand of leafy vegetables. The farmer is focused on growing his crop and is not aware of the consumers' expectations of the product. The wholesaler then has no idea how to deal with this changing pattern and will try hard to purchase vegetables from other provinces during the period of the year that the farmers in Shanghai cannot grow leafy vegetables. However, without cool storage the waste of products during warehousing and transporting is and will be enormous. Only the retailers are well aware of the changing spending patterns of the consumers in Shanghai and are aware of the trends in the future. Unfortunately, it is like “flogging a dead horse” to get the right leafy vegetables in their stores because of the lack of knowledge of how to deal with the products and the lack of cool storage and cooled transport (Voskamp, 2013).

2.4.3.2 Cold Chain Management for Vegetable Supply to Singapore Market

The vegetable supply chain of Singapore is relatively mature and is able to self-regulate and strives for better service and quality. Recent trends have been for major retailers like supermarkets to specify requirements for the postharvest handling of vegetables to be under cold chain management to maintain freshness and extend shelf-life of the produce for their consumers. Governments and industries have produced a “Technical Reference on Cold Chain Management of Leafy and Fruited Vegetables” that can serve as a reference for the supply chain players, from farm to fork. Cold chain management of vegetables begins at the farm, which is the first link of the cold chain. Cold chain management can delay the deterioration process of vegetables but cannot improve quality of vegetables if the quality at harvest is already poor. For good and premium quality of vegetables, farms would have to start with the adoption of good agricultural practice principles in farm operations and to implement proper postharvest handling. The pre-harvest condition of all vegetables determines the quality of the crop, which would affect the subsequent links of the cold chain. Harvesting of vegetables must be done at the right time, size, and quality and preferably under the shade to prevent excessive sunlight and heating of harvested produce. Good logistic planning of vegetables from farm to collecting center or packing house needs to be ensured for the best effectiveness and economics of the logistic flow (Siew and Lam-Chan, 2008).

In Singapore, the Agri-Food and Veterinary Authority of Singapore administers the Good Agricultural Practices (GAP) certification and also encouraged farmers to adopt the principles in their farming so as to ensure that the pre-harvest quality of vegetables are well taken care of. Generally farmers harvest in the late afternoon when the air temperature is not as high and deliver to the market in the early hours of the morning. The supply of vegetables from South East Asian countries like Malaysia, Indonesia, Thailand and Vietnam are mainly leafy green vegetables such as lettuces, fruited vegetables such as bitter gourd (*Momordica charantia*), lady’s finger (*Hibiscus* *esculentus*), chili (*Capsicum annuum*), cucumber (*Cucumis sativus*), eggplants (*Solanum melongena*), and sweet corn (*Zea maysvar. rugosa*). Sub-tropical vegetable types grown in highland regions of these countries ranges from leafy greens like lettuces to headed vegetables like cabbages, broccoli (*Brassica oleracea*), cauliflower etc. In most countries vegetables are either produced commercially or collected by middlemen from contract farmers for supplying targeted importers and supermarket chains in Singapore. Vegetable supplies arriving from China, USA and Australia are mainly temperate or sub-tropical varieties like tomatoes, peppers and headed vegetables such as broccoli, cabbage, potato, iceberg lettuce, celery, herbs and salad greens. The production bases for these vegetables vary with season and the time of the year and are usually grown in big commercial farms with good agricultural practices and greenhouses. The majority of the 180 to 200 supermarkets outlets in Singapore are implementing cold chain management of most vegetables sold under Hazard Analysis on Critical Control Points (HACCP) certification where cold chain management is one of the main requirements. Besides the supermarkets, institutional buyers like hotels, and Singapore Airport Terminal Services (SATS) kitchen are also implementing cold chain management for their fresh produce. With the increasing demand for safe and quality food, the benefits of cold chain are deemed as a necessity by an increasing number of importers and retailers (Siew and Lam-Chan, 2008).

Cold chain management and links

As most vegetable supplies have to travel long distances to reach the markets in Singapore, it is important to maintain the cold chain of the supply so that quality and freshness of vegetables can be maintained throughout the passage of handling and transportation. At a glance, the mode of transportation and number of hours taken for supplies from various parts of source countries to the Singapore market is shown in Table 2.5.

Table 2.5 Mode of transportation and number of hours taken for supplies from various parts of source countries to the Singapore market.

Source country	**Mode**	**Time (hr and d)**
Malaysia	Land	2-3 hr
Johor	Land	2-3 hr
Cameron Highlands	Sea	6-8 hr
Indonesia	Air	6 hr
	Sea	5 hr to 4 d
Thailand	Air (rarely)	3 hr
	Land	2 d
Vietnam	Air	2-3 hr
	Sea	2-3 d
China	Air	5-6 hr
	Sea	7-11 d
Australia	Air	6-10 hr
	Sea	12 d
New Zealand	Air	10-11 hr
USA	Air	16-17 hr
	Sea	21 d

Source: (Siew and Lam-Chan, 2008)

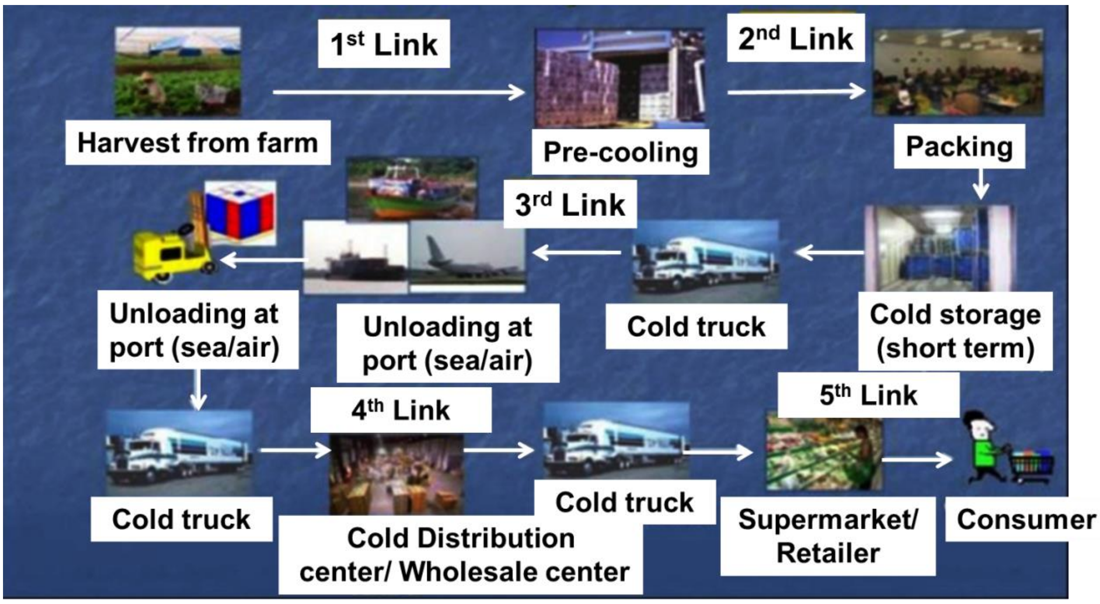

Figure 2.9 A schematic flow chart of the cold chain. (Siew and Lam-Chan, 2008)

From Table 1 above, freight time required by the 8 major vegetables exporting countries varies widely depending on the mode of logistics adopted, which can range from 2 h to 21 days, making cold chain management inevitable. A schematic flow chart of the cold chain is shown in Figure 2.9.

The Cold Chain can be sub-divided into 5 links, namely the farm, packing house, interface transportation, retail and consumer. Maintaining the Cold Chain integrity is the responsibility of every stakeholder who handles fresh produce, from producer, processor or packer, distributor, retailer to consumer. A break in any part along the chain, as in break in the temperature or humidity integrity and/or poor harvesting, packing, distribution procedure, will have an impact on the safety, quality, and perishable rate of the produce. The majority of the fruited and leafy vegetables are brought from neighboring countries to Singapore in open vehicles and in rattan baskets, with a resultant high spoilage (Siew and Lam-Chan, 2008).

The benefits of practicing cold chain management to the producers, importers and distributors are to achieve higher productivity, reduce spoilage and cost of disposal while to the consumers it would translate in quality and safety. Singapore as a net importer of vegetables would enjoy the cost benefits as well as a resilient and safe food supply. The good connectivity by road, air and sea and progressive development of cold chain technological know-how and equipment would continue to enhance the cold chain links for the supply of vegetables. However, there are challenges to overcome such as the increasing fuel cost, education of the many handlers along the supply chains and the quality of produce and packing materials. Tools are available to verify temperature fluctuations of the cold chain, such as data loggers, radio frequency identification device (RFID) tags, infrared thermometers, and thermo hygrometers, which are available and in place to maintain the integrity of the cold chain. The successes of the total cold chain management are more driven by consumer and market forces than regulators. The development of the Technical Reference would serve as an official standard for the buyers to request cold chain supply from sources (Siew and Lam-Chan, 2008).

2.4.3.3 Supply Chain Management for Vegetables in India

India produced around 146.55 MTs of vegetables, which accounts for nearly 14.0% of the country's share in the world production of vegetables. However, more than 70 types of vegetables are grown in this country, and a higher emphasis is given to more popular vegetables like tomato, chili, cauliflower, cabbage, peas, potatoes, onions and few common cucurbits and leafy vegetables. These also generate high income and employment, particularly for small farmers. Among the vegetables, potato is cultivated over large areas followed by onion and tomato, whereas the production of potato ranks first, followed by tomato and onion (National Horticulture Board, 2011). Though India has many positives in the vegetable production and marketing sector, it has several disadvantages too. The country lacks an efficient supply chain for the distribution of the vegetables (Kalidas et al., 2014).

The present supply chain that connects the farmers to both the organized as well as the unorganized retail is highly inefficient with several intermediaries and manual handling. The result is lots of waste, as much as nearly 30%, and also less remuneration for the farmers. There is a colossal waste during the postharvest storage and handling due to improper bagging without crating, lack of temperature controlled vehicles, no cold chain facilities for preserving the produce, coupled with significant processing of the agricultural produce resulting in enormous losses to the nation. Given the characteristics of fruits and vegetables such as perishability, seasonality, bulkiness and delicate nature of the products coupled with inadequate storage and transport facilities, the supply chain can be made efficient by reducing the length of the chain improving cold chain facilities. The supply chain management in vegetables has to be improved in all the stages of the supply by adopting best global practices in storage, packaging, handling, transportation, value added service etc. Also, by disintermediation and participation of organized players i.e., modern supply chains with a view to benefit both farmers as well as ultimate consumers (Kalidas et al., 2014).

Problems in Indian Food Supply Chain

Kalidas et al. (2014) reported that India has a huge opportunity to become a leading global food supplier if only it had an agile, adaptive, responsive and efficient supply chain. Some of the problems that are to be mentioned in the Indian food supply chain are:

a) Numerous stake holders working in isolation: The food supply chain is complex with perishable goods and numerous small stake holders. In India, the infrastructure connecting these partners is very weak.
b) Lack of demand estimation: Demand forecasting is totally absent and the farmers try to push whatever they produce into the market.
c) Lack of technology applications: Cold chain logistic supply chains should take advantage of technology improvements in data capture and processing, product tracking and tracing, synchronized freight transport transmit times for time compression along the supply chain and supply-demand matching.
d) Lack of system integration: The supply chain needs to be designed and built as a whole in an integrated manner. The process of new product development, procurement and order to delivery processes should be well designed and well supported with the help of IT tools and software.

Because of these problems in the Indian food supply chain, several initiatives should be taken to overcome the challenges (Kalidas et al., 2014).

a) The two golden rules for successful development of this sector are to ensure consistency in supply and to provide recorded and demonstrated traceability of products.
b) By creating vegetable supply chains and thus linking together farmers, vegetable vendors, farmer’s self-help groups and women vegetable vendors, ensuring consumers quality produce at a competitive price, at a convenient time and place.
c) By allowing more organized retailers to enter into the retail market. This would result in benefitting the farmers with good remunerative price and consumers with good quality produce.
d) Setting basic production factors, an optimal crop management system, and developing a postharvest infrastructure, entrepreneurial management and expertise and logistical infrastructure.

e) Improving postharvest operations related to handling, storage, and marketing of fresh and processed produce, which will reduce the losses incurred due to poor postharvest management and thereby ensuring adequate supply to the consumers.