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Reducing postharvest losses of tomato in traditional and modern supply chains in Cambodia

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Abstract

Traditional and modern supply chains for tomato in Cambodia were assessed and possible handling improvements were introduced. Traditional chain involved farmers and collectors in Kandal Province, and wholesalers and retailers in wet markets in the capital of Phnom Penh, about 35 km apart. In the modern chain, only one intermediary between farmers and supermarkets in Phnom Penh was involved; collector-wholesaler in Kandal Province or a development organization in Kampong Speu Province (65 km away from Phnom Penh) which consolidated farmers' produce through its packinghouse facility. Postharvest losses in the traditional and modern chains were about 23% and 22.5%, respectively, but the modern chain had more stringent quality requirements and offered higher prices than the traditional chain. Farmers' losses were mainly due to preharvest damage by insect pests and diseases and immaturity while losses during subsequent handling were due to physical damage, rotting, weight loss and/or over-ripening. Improved packaging, precooling and sanitizing treatments as individual handling improvements were tried in the traditional chain. Use of 20 kg capacity plastic crate with 50 µm-thick low density polyethylene (LDPE) bagging and 20 kg capacity bamboo basket lined with newsprint reduced fruit damage at the wholesale and retail stages relative to the conventional packaging of using 20 kg capacity 50 µm-thick high density PE (HDPE). More dramatic effect on weight loss reduction was obtained with both conventional HDPE and plastic crate-LDPE packaging methods. Precooling (5 min dip in 5oC water) and chlorine wash (2 min dip in 200 ppm chlorine solution) combined with LDPE packaging had no pronounced effect on the incidence of fruit damage but reduced weight loss at the retail stage by about two-fold compared to that of fruit conventionally packed in HDPE bag without precooling or chlorine treatment. For the modern chain, modified atmosphere packaging (MAP) comparing LDPE and 11 µm-thick film overwrap was tried under simulated supermarket conditions (15oC). Fruit weight loss and ripening were inhibited relative to that at ambient (24-33^{o}C, 65-92% RH). MAP had no appreciable effect on weight loss at 15^{o}C but further retarded ripening based on colorimetric a* values (red color), soluble solids and citric acid contents. Film overwrap was more effective than LDPE. The results indicate that the handling techniques introduced could be applied in tomato supply chains to reduce postharvest losses.

Introduction

Cambodia is an agrarian country with its economic foundation based largely on the agriculture sector (Ministry of Agriculture, Forestry and Fisheries, 2009). Agriculture generates 32% of gross domestic product, with crops as the leading contributor (52%) followed by fisheries (25%), livestock (16%), and forestry (7%) (National Institute for Statistics, 2009). Agriculture occupies about 24% of the country's total land area of about 180,000 km^2. About 80% of the population of 14 million and 75% of the rural poor depend on agriculture for their livelihoods.

Tomato is among Cambodia's major vegetables, the fourth leading agricultural crop (National Institute for Statistics, 2009). In recent years, tomato production is expanding due to the introduction of improved varieties and production techniques as well

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as increased market demand and entry of modern market outlets, in particular supermarkets, hotels and restaurants due to the flourishing tourism industry. However, poor postharvest practices are serious concerns and contribute to the poor quality perception and high postharvest losses of domestically produced tomato (Genova *et al*., 2006). Postharvest losses also contribute to the country's high dependence on vegetable imports estimated at about 70% on average; in tourist areas, as much as 90% are sourced from neighboring Vietnam and Thailand due to supply reliability of quality produce (Acedo *et al*., 2010). Reducing postharvest losses is one of the strategies for import substitution and a positive step toward vegetable self sufficiency. A supply chain approach to postharvest loss reduction has become essential to improving marketing efficiency and profitability and creating significant market advantage. This study mapped the traditional and modern supply chains for locally produced tomato, assessed postharvest losses, and introduced improved packaging, precooling and sanitizing treatments as individual handling improvements in the traditional chain, and modified atmosphere packaging (MAP) in the modern chain as possible techniques to reduce postharvest losses.

Materials and Methods

Assessment of supply chains and postharvest losses

Traditional and modern supply chains and postharvest losses of tomato were assessed in July 2009 – March 2010. The traditional supply chain covered major growing areas in Kandal Province up to the retail markets in Phnom Penh, the capital of Cambodia. This was compared with modern supply chains for tomato produced in Kandal and Kampong Speu provinces for supermarkets in Phnom Penh. Figure 1 shows the country location of the study areas. Information on major growing areas and supply chain routes were obtained from district agriculture officers and village heads. To obtain postharvest loss estimates and their causes, on-site interviews were conducted involving 30 farmers, 30 collectors, 30 wholesalers from the two biggest wholesale markets (Deum Kor and Neak Meas markets) in Phnom Penh, and 35 wet market retailers for the traditional chain, and 30 farmers and 30 collectors from Kandal and Kampong Speu provinces including representatives from the development organization, Peri-Urban Agricultural Center, as distribution or marketing arm serving the Lucky Supermarket chain, and supermarket managers for the modern chain. The results were analyzed using the SPSS program at 95% confidence level and reported here as averages and frequencies.

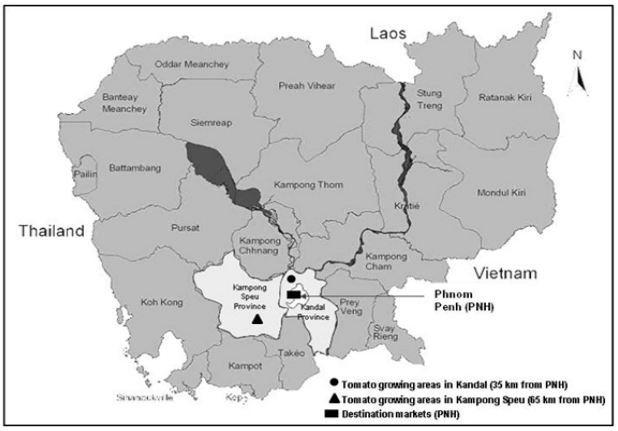

Figure 1. Map of Cambodia showing tomato growing areas in Kandal and Kampong Speu provinces and destination market in Phnom Penh as study sites for the traditional and modern supply chains

Application of postharvest techniques in the traditional supply chain

Improved packaging, precooling and sanitizing treatments were introduced following the findings of prior optimization trials and were evaluated for their comparative effectiveness. Freshly harvested breaker tomatoes of the commercial variety TMK1 from a farmer in Kandal province were used in the trials. In the packaging trial, the use of rigid containers, 20 kg capacity plastic crate lined with 50 µm-thick low-density polyethylene (LDPE) film with two 15 mm-diameter holes per kg and 20 kg capacity bamboo basket lined with newsprint, was compared with the conventional practice of using 20 kg capacity 50 µm-thick high-density PE (HDPE) bags without holes. This was applied at the farmer level. After filling the container, the HDPE or LDPE film was tied with a rubber band while the bamboo basket was covered with three layers of newsprint before securing with a plastic straw. The treatments were replicated three times. Fruit damage, weight loss, and peel color changes of 10 fruit samples per replicate measured as a* values (red color) with a Minolta CR-13 colorimeter were monitored at each supply chain stage, i.e. from the farmer to collector, from collector to wholesaler, and from wholesaler to retailer stages. Results were analyzed using the IRRISTAT Program for Windows Version 5.0.20050907. The time period between each chain stage including delays while waiting for transport was about 5 hours from harvesting to transport to the collector, 5 hours from the collector to wholesaler, and 6 hours from the wholesaler to retailer. Temperatures and relative humidity (RH) during the study ranged from 29-33.8^{o}C and 39.7-67.5%, respectively.

In the trial employing precooling and sanitizing treatments, fruit were dipped in 5^{o}C water for 5 min or in 200 ppm chlorine solution for 2 min prepared

using the commercial bleach. After air-drying, fruit were packed in 50 µm-thick LDPE with two 15 mm-diameter holes per kg. This was compared with untreated fruit conventionally packed in 50 µm-thick HDPE bags without holes at 20 kg fruit per bag. The treatments were replicated three times and applied at the farmer level. Measurement and analysis of data followed the same procedures as that in the packaging trial. The time period between each chain stage including delays was about 7 hours from harvesting to transport to the collector, 5 hours from the collector to the wholesaler, and 8 hours from the wholesaler to the retailer. Temperatures and RH during the study ranged from 26-32.5°C and 55.7-90.6%, respectively.

Application of modified atmosphere packaging in the modern supply chain

Freshly harvested TMK1 tomatoes at the breaker stage were obtained from a local farm in Kampong Speu Province and subjected to MAP treatments under simulated supermarket conditions of 15°C. Ambient holding (24-33°C, 65-92% RH) was included for comparison purposes and additionally, for possible application of MAP during ambient retail which was prevalent in traditional chains. MAP treatments included packing fruit in 50 µm-thick LDPE bag and overwrapping fruit on foam tray with 11 µm-thick plastic film wrap. Fruit held in the open served as control. The treatments were replicated three times with 0.5 kg fruit per replicate. Fruit responses were periodically measured and included weight loss as percent of initial weight, red color development as a* values taken using a colorimeter, total soluble solids (TSS) measured using a refractometer, and titratable acidity (TA) determined by titration against a standard base and expressed as percent citric acid. Results were analyzed using the IRRISTAT Program.

Results and Discussion

Supply chain practices

Figure 2 illustrates the traditional and modern supply chains for tomato. The traditional chain consisted of four levels, farmers and collectors in Kandal Province, and wholesalers and retailers in Phnom Penh. Farmers dealt with collectors who may also be contract buyers in the province. The collectors delivered the produce to Deum Kor Wholesale Market in Phnom Penh, about 35 km away, where wholesalers bought them for distribution to retailers in the city. Aside from Phnom Penh retailers, wholesalers catered to retailers in other provinces.

The modern chain was straightforward, involving

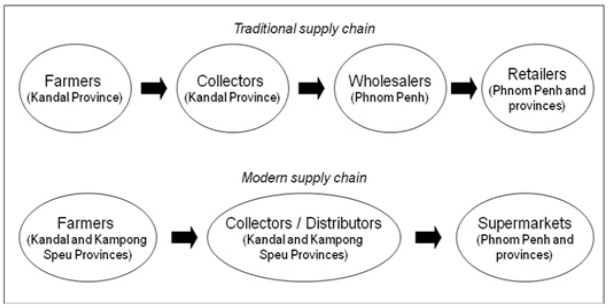

Figure 2. Traditional and modern supply chains for tomato in Cambodia

only one intermediary between the farmers and supermarkets. For tomatoes produced in Kandal province, the collector-wholesaler procured the fruit from farmers and distributed them to supermarkets in Phnom Penh based on prearranged order or contract. For tomatoes produced in Kampong Speu province, about 65 km away from Phnom Penh, farmers were contracted by a development organization, Peri-urban Agricultural Center (PUAC), with a distribution center in Phnom Penh serving supermarkets. PUAC had a packinghouse facility where cleaning, sorting and packing of tomatoes were done and a dedicated truck for product transport to its distribution center in Phnom Penh.

Tomatoes in the traditional and modern supply chains were manually harvested at breaker or ripe stages based on the requirements of collectors or markets. Farmers knew how to do sorting/grading which was based on a combination of fruit quality attributes such as size, shape, and freedom from defects. Some farmers still placed the harvested tomatoes directly on the ground, a rich source of microbial pathogens, while most of them used tarpaulin or other lining materials as ground cover. However, tomatoes of different stages of ripeness were packed together often using 20-25 kg capacity plastic bags and in certain cases, 200 kg capacity bamboo baskets.

Collectors, collector-wholesalers and distributors sorted tomatoes into two to three grades based on size and freedom from defects, with 0.18-0.30 USD/kg price difference between grades. Sorting was mostly done on wooden or bamboo table and in some cases, on the ground covered with mat, sack, plastic sheet or tarpaulin. A few collectors sorted tomatoes on the ground without cover. Motorbike and motor trailers were the most common transport medium from the farm to retail.

In the modern supply chain from Kampong Speu to Phnom Penh with support from PUAC, tomatoes were sorted and packed in plastic bags in the packinghouse, and placed in the ice-cooled cargo compartment of a truck for transport to the

Table 1. Postharvest losses of tomato in the traditional and modern supply chains in Cambodia

Supply chain actor	Postharvest loss, %	Major causes of loss*	Price of tomato, USD
Traditional supply chain			
Farmers	12.5	Immaturity Insect damage Rotting/decay	0.200
Collectors	3.5	Physical damage Rotting/decay	0.273
Wholesalers	3.5	Physical damage Rotting/decay	0.365
Retailers	3.5	Physical damage Rotting/decay Over-ripening	0.527
Total loss	23.0		
Modern supply chain			
Farmers	12.5	Immaturity Insect damage Rotting/decay	0.375
Collector-wholesalers/ distributors	5.0	Weight loss Physical damage Rotting/decay Over-ripening	0.625
Supermarkets	5.0	Physical damage Rotting/decay Over-ripening	0.950
Total loss	22.5		

*with > 50% frequency

Table 2. Factors contributing to postharvest losses of tomato in the traditional and modern supply chains in Cambodia (frequency in %)[1]

Factor	Farmers	Collectors	Wholesalers	Retailers/ Supermarkets
Hot and humid weather	100	33		
Poor packaging material		27	30	3
Poor storage conditions		13	68	68
Poor transport system		17	43	52
Poor sanitation	3	3	37	
Inability to sell all produce		10	43	71

[1]multiple responses

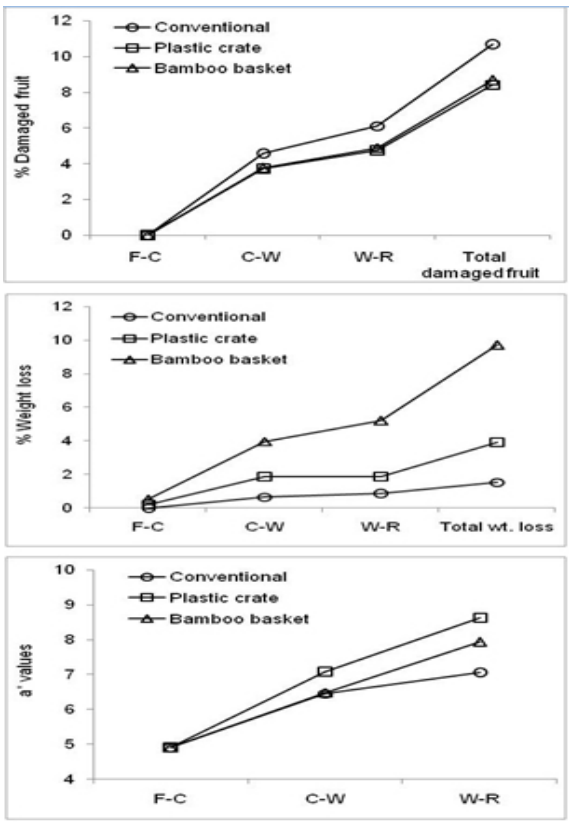

Figure 3. Effects of packaging on tomato fruit damage, weight loss and reddening (a*) at the farmer-collector (F-C), collector-wholesaler (C-W) and wholesaler-retailer (W-R) stage in the supply chain

distribution center in Phnom Penh where re-sorting and re-packing were done. The distribution center and some wholesalers have contract arrangement with their trading partners.

Postharvest losses

Farmers in both traditional and modern chains incurred the highest loss of 12.5% on average mainly due to preharvest causes, i.e. fruit immaturity, insect damage and diseases/rotting (Table 1). Collectors, wholesalers and retailers in the traditional chain incurred an average loss of 3.5% each due to physical damage and decay or rotting. The total loss in the traditional chain amounted to 23%.

In the modern chain, collector-wholesalers or distributor (i.e. PUAC) and supermarkets incurred an average loss of 5% each due to physical injury, decay/rotting, over-ripening and weight loss (Table 1). Total loss (22.5%) was almost the same as that in the traditional chain. However, the modern chain had more stringent quality requirements partly depicted as much higher prices of produce than that in the traditional chain (Table 1). Fruit even with slight physical or biological damage were rejected, which was not the case in the traditional chain.

Farmers and collectors singled out the hot and humid weather as the main factor contributing to fruit losses (Table 2). Collectors also identified poor packaging, storage and transport as contributory factors to losses. Wholesalers identified several problems including poor packaging, transport and storage conditions, poor sanitation, and inability to sell all produce. For retailers/supermarkets, inability to sell all produce and poor storage conditions were the main factors contributing to losses.

Based on the results, technological interventions are needed to minimize fruit damage and weight loss during handling and transport and reduce weight loss during retail or supermarket display.

Application of packaging methods in the traditional chain

Treatment effects were evident only at the wholesale and retail stage (Figure 3). Damaged fruit were lower in plastic crate-LDPE and bamboo basket packaging than in the conventional HDPE packaging. However, treatment differences were not remarkable in contrast to that on weight loss. Both conventional HDPE and plastic crate-LDPE packaging methods greatly reduced weight loss at the wholesale and retail stages relative to that of bamboo basket packaging. Red color development of the fruit did not vary much with packaging method, with a* values of 6-7 at the wholesale stage and 7-8.5 at the

Table 3. Total soluble solids (TSS) and citric acid contents of tomatoes with or without MAP after 15 days storage at 15°C or at ambient

Treatments	% TSS	% Citric acid
15°C – open	3.95b	0.44a
15°C – LDPE	3.67cd	0.35b
15°C – film overwrap	3.35d	0.45a
Ambient – open	4.27a	0.30c
Ambient – LDPE	4.30a	0.34bc
Ambient – film overwrap	3.82bc	0.36b
% CV	4.0	9.8

Mean separation within columns by DMRT, 5%

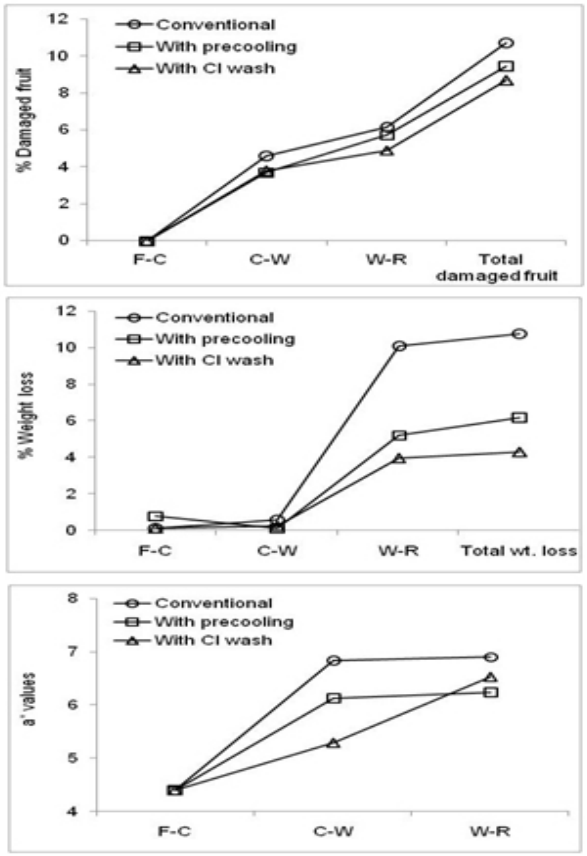

Figure 4. Effects of precooling and chlorine wash on tomato fruit damage, weight loss and reddening (a*) at the farmer-collector (F-C), collector-wholesaler (C-W) and wholesaler-retailer (W-R) stage in the supply chain

retail stage from an initial level of about 5 indicating that the fruit remained mostly at the breaker stage on arrival at retail. Full red tomatoes usually have a* values of more than 20.

The results show no dramatic reduction of fruit damage with the use of rigid containers such as plastic crates and bamboo baskets over a distance of about 35 km and time period of about 16 hours. However, use of polymeric films such as HDPE and LDPE even with ventilation holes proved to be very effective in minimizing weight loss. This is consistent with the findings of a previous study optimizing MAP for tomato in Cambodia (Vanndy *et al*., 2008).

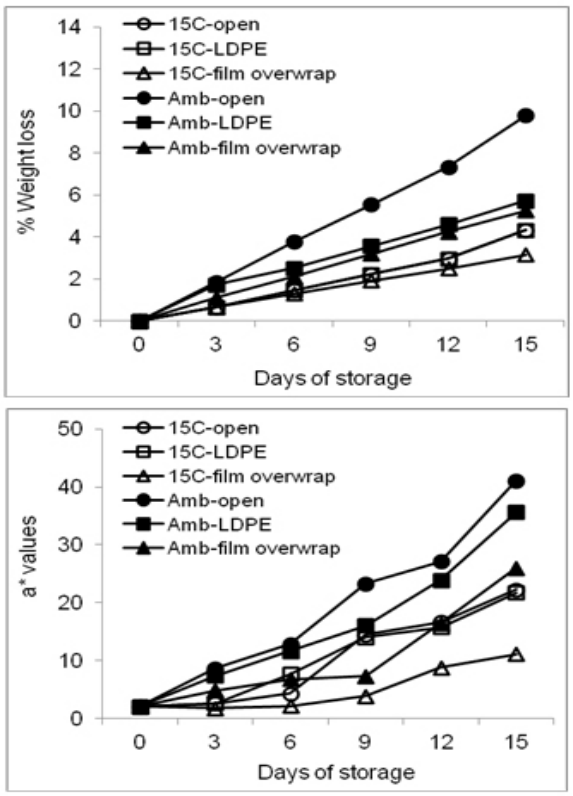

Figure 5. Weight loss and reddening (a*) of tomatoes with or without modified atmosphere packaging during storage at 15°C or at ambient

Application of precooling and chlorine wash in the traditional chain

Precooling and chlorine wash combined with LDPE packaging had no pronounced effect on the magnitude of damaged fruit along the supply chain (Figure 4). Marked differences in weight loss were however noted at the retail stage. Precooling and chlorine wash reduced weight loss by about two-fold relative to that of untreated fruit. Fruit reddening associated with ripening appeared to slow in response to precooling and chlorine washing which can be seen at the wholesale stage; however, the a* values ranging from 4-7 from the farm to retail stage indicate that ripening has not progressed much similar to that obtained in the packaging trial. These effects of precooling and chlorine wash in combination with MAP were similarly obtained in earlier optimization studies adopting precooling and chlorine treatments (Acedo *et al*., 2009a, 2009b) for enhancing quality and shelf life of tomatoes in Cambodia (Buntong, 2010).

Application of MAP in the modern chain

Fruit weight loss increased with storage (Figure 5). It was significantly lower in fruit stored at 15°C than at ambient. MAP did not further reduce weight loss at 15°C but remarkably decreased that at ambient. MAP using LDPE or film overwrap was comparably effective. Similarly, fruit reddening proceeded most

rapidly in the open at ambient expressed as increasing a* values with advancing period of storage (Figure 5). Storage at 15°C and MAP slowed fruit reddening. Between the two MAP treatments, film overwrap seemed to be more effective than LDPE in retarding reddening both at ambient and at 15°C. At the end of the 15-day storage period, TSS was lower while citric acid content was higher in fruit stored at 15°C especially with film overwrap (Table 3), indicating less advanced ripening stage than that stored at ambient.

Low temperature storage is well known to be the most effective method of prolonging shelf life of fresh produce including tomatoes (Thanh, 2006). Typical effects include weight loss reduction due to reduced rates of transpiration and respiration and retardation of ripening. Similarly, MAP has been found to reduce weight loss, slow ripening, and increase shelf life of tomatoes due to the maintenance of low oxygen, high carbon dioxide and humid atmosphere (Batu and Thompson, 1998; Yaptenco *et al*., 2004). The results of the present study confirm the favorable effects of low temperature and MAP on shelf life of tomato.

Conclusion

Traditional supply chain for tomato was more complex than modern supply chain. In both chains, fruit losses were almost the same but the quality and price of tomatoes in the modern chain were higher than that in the traditional chain. MAP, precooling and chlorine wash have potential in reducing postharvest losses and in improving efficiency of supply chains.

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