Quality and Safety Issues in Fruit and Vegetable Supply Chains in Sri Lanka: A Review

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Research Report No: 217 June 2018

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Final typesetting and lay-out by: Dilanthi Hewavitharana

ISBN: 978-955-612-238-1

FOREWORD

Controlling quality and assuring safety of fruits and vegetables in supply chains are among critical challenges faced by Sri Lanka. In the recent past various malpractices were recorded throughout the supply chains by various actors such as farmers, collectors and traders. In addition to post-harvest losses, food adulteration with harmful chemicals reached an alarming level posing numerous health hazards. Therefore, food safety issues need to be extensively investigated to examine the impact of current levels of practices. This research report reviewed the issues related to the post-harvest losses, current measures to minimize and overcome them and the safety issues related to food adulterations in fruit and vegetable supply chains in the country through a comprehensive literature survey.

This review highlighted that the quality and safety of fruits and vegetables produced in Sri Lanka suffer from improper pesticide and fertilizer use, poor methods and practices starting from the production stage to post-harvest measures and there is minimal intervention at the production or growing stage to ensure quality and safety. It also provides valuable insights into pesticide usage in Sri Lanka and identifying problematic areas related to food safety in the country.

This review emphasizes the need for formulating a national policy to minimize post-harvest losses of fruits and vegetables and increased state intervention to improve the post-harvest handling conditions towards uplifting the socio-economic status of the stakeholders in fruit and vegetable supply chains. Implementation of a cost effective safety assurance system for consumer satisfaction and a separate market window to provide safe vegetables to consumers are also highlighted.

Therefore, I believe that the findings and recommendations of this report would be useful to policymakers and other relevant stakeholders towards assuring the quality and safety of fruits and vegetable supply chains in the country.

K.W.E. Karalliyadda
Director

ACKNOWLEDGEMENTS

The authors are thankful to Mr. K.W.E. Karalliyadda, Director of HARTI for his constant support in publishing the report. Professional support extended by Mr. R.L.N. Jayatissa, Additional Director (Research) of HARTI, throughout the study is highly appreciated. The research team also expresses sincere thanks to Mr. W.H.D. Priyadarshana, Head, Marketing, Food Policy and Agri-business Division of HARTI for his comments on the preliminary draft.

We extend our great appreciations to Dr. Ananda Jayalal, Deputy Director, Environment, Occupational Health and Food Safety Division, Food Control Administrative Unit, Ministry of Health and his staff; Mr. R.M.G.B. Rajanayake, City Analyst, Colombo Municipal Council; Ms. Anoma Senevirathne, Food Research Unit, Department of Agriculture; Dr. Sumith Jayakodi, Acting Registrar of Pesticide and Ms. R.A.P. Ranaweera, Head, Import Permit Division, National Plant Quarantine Services for providing us vital information during the key informant interview survey.

We are also grateful to the librarians of the Universities of Ruhuna, Peradeniya, Kelaniya, Colombo, Sri Jayawardhanapura, Rajarata, Wayamba, Post Graduate Institute of Science and Post Graduate Institute of Agriculture, National Science Foundation, Industrial Technology Institute for their valuable support for the literature survey.

We very much appreciate the valuable comments given by the external reviewers, Dr. (Mrs). Ilmi Hewajulige, Senior Deputy Director, Food Technology Section, Industrial Technology Institute and Dr. S.K.D.F. Niranjan, Senior Research Officer, Sri Lanka Council for Agricultural Research Policy . Their excellent feedback was instrumental in improving the report.

Thanks are due to Ms. M.N. Wijenayaka, Statistical Assistant of HARTI and Ms. H.I.U.N. Muthukumara and Mr. P.H.K.D. Thirimanna, Casual Investigators of this project for assisting data collection, review of literature and data analysis. We are also grateful to Ms. L.K.A.C. Dahanayake, Assistant Registrar (Programme), HARTI and her staff for providing administrative facilitation throughout. We are also thankful to Ms. Suharshi Perera for expert editorial assistance and Mr. C.U. Senanayake for proofreading of the report. Our thanks are also extended to all the staff of MFPA Division in HARTI for providing us all forms of support. Finally, we wish to thank the staff members of the Publication Unit of HARTI for publishing the report.

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EXECUTIVE SUMMARY

Fruits and vegetables make a significant contribution to food security, nutrition, poverty reduction and promoting economic development. The potential of cultivating fruits and vegetables in Sri Lanka for domestic and export markets is remarkable. This sector can make significant strides if developed it. Similarly improving the quality and safety of fruits and vegetables supplied to domestic and export markets is important considering the significant contribution it can make to increase the level of national income, generate new employment opportunities, increase farm income and enhance nutrition and health of the people. Poor quality and safety are the major roadblocks found in traditional fruit and vegetable supply chains mainly due to poor handling/sorting, inappropriate storage and transport, improper pesticide and fertilizer use. The growing public concern over the quality deteriorated due to post-harvest losses and presence of chemical residues in the harvested fruits and vegetables has become a pressing issue in Sri Lanka. In the recent past various malpractices committed by various actors such as farmers, collectors, and traders throughout the supply chains were reported. In addition to post-harvest losses, food adulteration with harmful chemicals reached an alarming level causing numerous health hazards. Therefore, the objectives of this study were to review issues related to post-harvest losses and food adulterations (E.g. pesticides, ripening agents, and preservatives) in fruit and vegetables supply chains in Sri Lanka and to identify studies towards minimizing and overcoming post-harvest losses in the country. Identifying the institutional level measures to minimize quality and safety issues in fruits and vegetable supply chains in the country is another aim. The literature survey was based on academic papers and industry related documents.

Quality and safety of fruits and vegetables produced in Sri Lanka suffer from improper pesticide and fertilizer use, poor methods and practices from production to post-harvest stage. There is minimal intervention at the production or growing stage to ensure quality and safety. Post-harvest losses of fruits varied between 20-40 percent with the highest loss recorded for papaya and for vegetables it was 20-46 percent with the highest loss recorded for okra due to unsatisfactory packaging, lack of ventilation in the lorries, poor facilities for handling produce in the Colombo wholesale market and the extreme traffic congestion and inordinate delays before unloading. However, the loss is minimum in supermarket chain reported as two to six percent and five to ten percent in export chains. The most important post-harvest diseases and disorders in Sri Lanka are anthracnose, stem end rot, water blister and internal browning of pineapple. Soft nature of fruits and vegetables, high water content and high rate of respiration contribute to losses. Bruising is the major factor causing rotting. Horticultural products are easily bruised, rendering the product unsaleable due to their soft texture. Therefore, all horticultural products should be handled gently to reduce losses due to bruising and rotting. Bruising is probably one of the major causes of losses in Sri Lanka.

The Institute of Post-Harvest Technology (IPHT) launched a development project to introduce plastic crates to fruit and vegetable supply chains at 50 percent and 75

percent subsidized prices to curtail the losses. Furthermore, a regulation came into force making safe packaging compulsory for fruit and vegetable transportation to minimize post-harvest losses and to ensure supply of quality produce to the consumer. However, studies show that the use of safe packaging was limited due to many constraints and limitations. Most common were unavailability of plastic crates, high cost of transportation, load transported per journey being limited due to safe packaging and absence of an assured mechanism of returning safe packages moving through the supply chain. Unlike for vegetables, safe packages are used for packing and transporting fruits such as mango, papaya and guava in conventional supply chains. Mostly used safe packages were plastic crates, corrugated fiberboard boxes and wooden boxes.

Improved technologies alone cannot prevent post-harvest losses because the effect of the pre-harvest factors such as crop management, field sanitation also contributes to crop losses. Pre-harvest fungicide treatment, sanitation, bagging and other field management practices and careful post-harvest handling can reduce a majority of post-harvest disease problems. Factors affecting the safety of fruits and vegetables include naturally-occurring toxicants, natural contaminants such as fungal toxins (mycotoxins) and bacterial toxins and heavy metals (cadmium, lead, mercury); environmental pollutants; pesticide residues and microbial contamination. The problem of contamination of food sources, especially vegetables by pesticide residues poses a serious challenge to public health. Pesticide usage is not properly regulated due to ineffective legislation, lack of awareness and technical know-how among the farming community in Sri Lanka. Except a few monitoring studies, no comprehensive studies have been undertaken to determine the pesticide residues in vegetable and fruit in the country. Farmers lack information and knowledge on the safe and effective use of pesticides.

Globalization of the food supply chain has posed new challenges by way of food safety and quality issues. With increased trade in fresh and processed food, there is a growing concern about food safety issues in Sri Lanka. When exploiting the export potential for fruits and vegetables, the safety risk of these foods to meet international market requirement is necessary. It is important to maintain higher levels of quality and safety measures consistent with EU regulations and US Food and Drug Administration. Therefore, effective quality control systems are needed to meet export market requirements for fresh and processed fruits and vegetables from Sri Lanka. In September 2016, there was an audit by the EU to evaluate control of pesticides in food of plant origin. When exporting to those countries, it is important to have GAP certificate from the Department of Agriculture (DOA). As a solution for safety and quality issues in agriculture products, the Good Agricultural Practices (GAP) programme was introduced in January 2015. Under this, application of fertilizer, pesticide and weedicide, harvesting, processing, transportation, grading, packing, value addition, labeling, distribution and storage processes will be monitored by the Department of Agriculture. This will help control microbial, chemical and physical hazards associated in all stages from production to packaging of fruits and vegetables.

In Sri Lanka, the task of ensuring food safety is conducted in a largely adhoc manner, tasks are dispersed to a number of government agencies and departments such as the Department of Agriculture, Consumer Affairs Authority, the Sri Lanka Standards Institute, Atomic Energy Authority, Sri Lanka Customs – Quarantine Department and the Ministry of Health, based on their respective areas of expertise. Lack of sufficient national standards to measure food safety and effective institutional mechanism to enforce food safety at different stages in the food chain are the major issues related to food safety in the country. Sri Lanka Food Act No.26 of 1980 is the main legislative document covering some aspects of food safety. The Act is basically implemented through Director Health Services (DHS) in the Ministry of Health, Nutrition and Indigenous Medicine through local authorities and respective MOH offices in the region. DGHS is the chairman of Food Advisory Committee (FAC) consisting 25 representatives from agencies implementing various aspects outlined in the Act.

The official inspection service under the Food Control Administration Unit (FCAU) lacks coordination and integration with other government agencies of the local food chain while public based health surveillance system lacks muscle and time to cover agricultural produce and supplies aspects.

Use of synthetic chemicals that induce fruit ripening is a persistent issue in Sri Lanka. Although section 26 of the food regulation of 1993 explicitly prohibits the use of calcium carbide it is practised unabated with regard to artificial fruit ripening. Excessive use of these chemicals poses a serious threat to human health. This review emphasizes the need for a national policy to minimize post-harvest losses of fruits and vegetable the government to take initiatives and allocate resources to improve the post-harvest handling conditions, thereby improving the socio-economic status of the stakeholders in fruit and vegetable supply chains.

It was found that malpractices observed in fruit and vegetable supply chains can largely be attributed to poor knowledge of stakeholders associated with fruit and vegetable chains. As a result the consumer will fall prey to the improper use of pesticides. Therefore, education and training of these farmers in pesticide management is a timely move. Farmers' safe handling of pesticide should be looked into. Training of farmers in post-harvest handling, food safety both for the domestic market and international trade is important. Strict enforcement of laws curbing production and sale of fruits and vegetables subject to harmful chemical exposure should be observed.

This review highlights the importance of continued research to develop easy-to-use practical test kits to identify chemicals, pesticides, additives, preservatives and toxic elements at production, processing, distribution and consumption levels. Investment is a vital component in developing testing infrastructure to achieve international standards and accreditation.

Further, the study underlines the need for a cost effective safety assurance system for the higher satisfaction of consumers by the government with a separate market window to provide safe vegetables to consumers. Strict regulations on the quality of imported fruits are also important.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ADI	-	Acceptable Daily Intake
AO	-	Authorized Officers
ARD	-	Acute Reference Dose
AVA	-	Agri-food and Veterinary Authority
BHA	-	Butylated Hydroxyanisole
BHT	-	Butylated Hydroxytoluene
BIS	-	Bureau of Indian Standards
CA	-	Controlled Atmosphere
CAA	-	Consumer Affairs Authority
CAB	-	Counselors in Agri-business
CCPR	-	Codex Committee on Pesticide Residues
CFA	-	Chief Food Authority
CFB `	-	Corrugated Fiberboard
CMC	-	Colombo Municipal Council
CMOH	-	Chief Medical Officer of Health
DC	-	Distribution Centre
DEC	-	Dedicated Economic Centre
DGHS	-	Director General of Health Service
DHS	-	Director Health Services
DOA	-	Department of Agriculture
EDB	-	Export Development Board
EFSA	-	European Food Safety Authority
EU	-	European Union
F&DI	-	Food and Drug Inspector
F&V	-	Fruits and Vegetables
FAC	-	Food Advisory Committee
FAMA	-	Federal Agriculture Marketing Authority
FAO	-	Food and Agriculture Organization
FCAU	-	Food Control Administrative Unit

FI	-	Food Inspectors
FMP	-	Fused Magnesium Phosphate
FQSA	-	Foodstuff Quality and Safety Assurance
FSSAI	-	Food Safety and Standards Authority of India
GA	-	Gibberellic Acid
GAP	-	Good Agricultural Practice
GHP	-	Good Hygiene Practices
GMP	-	Good Manufacturing Practice
HACCP	-	Hazard Analysis Critical Control Point
IB	-	Internal Browning
IFOAM	-	International Federation of Organic Agriculture
IPHS	-	Improved Post-harvest Handling Systems
IPHT	-	Institute of Post-harvest Technology
ISO	-	International Organization for Standardization
ITI	-	Industrial Technology Institute
JAS	-	Japanese Agricultural Standard
LDPE	-	Low Density Polyethylene
LOAM	-	Lanka Organic Agriculture Movement
LOQ	-	Limit of Quantification
MA	-	Modified Atmosphere
MAP	-	Modifies Atmosphere Packaging
MOH	-	Medical Officer of Health
MRI	-	Medical Research Institute
MRL	-	Maximum Residue Limit
NAQS	-	National Agricultural Quality Management Service
NERD	-	National Engineering Research and Development
NFPPA	-	National Food Policy Plan of Action
NGO	-	Non-Government Organizations
NIHS	-	National Institute of Health Sciences
NPQS	-	National Plant Quarantine Service

OECD	-	Organization for Economic Cooperation and Development
PE	-	Polyethylene
PFA	-	Prevention of Food Adulteration
PH	-	Post-harvest
PHI	-	Public Health Inspectors
PHL	-	Post-harvest Losses
PSC	-	Phytosanitary Certificate
PSI	-	Post-harvest System Improvement
PVC	-	Polyvinyl Chloride
QAP	-	Quality Assurance Programme
QS	-	Quality and Safety
RH	-	Relative Humidity
RTS	-	Ready-To-Serve
SAARC	-	South Asian Association for Regional Cooperation
SARSO	-	South Asian Regional Standards Organization
SATNET	-	Network for Knowledge Transfer on Sustainable
SGS	-	General Society of Surveillance
SLAB	-	Sri Lanka Accreditation Board
SLS	-	Sri Lanka Standard Specifications
SLSI	-	Sri Lanka Standards Institute
SPS	-	Sanitary and Phytosanitary
TBT	-	Technical Barriers to Trade
U.A.E	-	United Arab Emirates
UNCTAD	-	United Nations Conference on Trade and Development
US	-	United States
USA	-	United States of America
WHO	-	World Health Organization
WTO	-	World Trade Oragnization
WTP	-	Willingness to Pay

CHAPTER ONE

Introduction

1.1 Research Background

Fruits and vegetables are highly valued in human daily diet mainly for vitamins, minerals and antioxidants. Assuring adequate intake of nutritious and safe fruits and vegetables can greatly contribute to the attainment of food and nutrition security of any nation. Present consumption of fruits and vegetables in Sri Lanka is 100g/day/capita and 114g/day/capita respectively (Ministry of Agriculture, Sri Lanka, 2015), which is far below the minimum average requirement of 400g of fruits and vegetables/day/capita (Ministry of Health, Sri Lanka, 2011), which indicates poor dietary status in Sri Lanka. Increased consumption of a variety of fruits and vegetables on a daily basis is highly recommended because of associated health benefits which include reduced risk of some forms of cancer, heart disease, stroke and other chronic diseases.

Fruits and vegetables make a significant contribution to food security, nutrition, poverty reduction and in generating economic development of a country. Poor quality, questionable safety and high post-harvest losses are major bottlenecks faced in traditional fruit and vegetable marketing chains. Many of the stakeholders associated with fruit and vegetable chains lack basic knowledge of the factors that could compromise the quality and safety of fresh produce during harvesting and post-harvest handling operations. The quality and safety of fruits and vegetables produced in Sri Lanka suffer due to improper pesticide and fertilizer use, poor handling/sorting during collection, inappropriate storage and transport.

Due to tropical and subtropical climates, a range of fruits and vegetables grow in Sri Lanka, but a considerable proportion (30-40%; Fernando, 2006) never reaches the consumers mainly because of post-harvest losses. Hence, any attempt to minimize post-harvest losses and maintain quality and safety in horticultural chains are important. For the quality and safety of horticultural produce reaching the consumers, pre-harvest factors as well as proper post-harvest management practices throughout the chain, from the field to the consumer is important. Each stakeholder along the post-harvest chain i.e. those involved in harvesting, handling and marketing of fresh produce has a role to play in assuring safety and quality of fresh produce.

According to the FAO estimates, 10-30 percent of the basic food supply such as cereals, pulses, oil seeds and tubers and up to 50-60 percent of the fruits and vegetables are lost after harvesting before reaching the consumer (Ranaweera and Bamunuarachchi, 2005). Inadequate conservation and storage facilities and lack of marketing structures lead to the spoilage of large quantities of agricultural produce in many tropical and subtropical countries. Losses can be classified as physical and

economic. Most are preventable if possible causes of the losses and their nature are identified.

Common reasons for post-harvest losses of fruits and vegetables are: physiological and biochemical processes after harvest (respiration, ethylene production and water loss by transpiration), microbial decay, disorders, poor and short storage characteristics and sub-standard post-harvest handling infrastructure. In addition to post-harvest losses, food adulteration with harmful chemicals has reached an alarming level, posing health hazards in the country. Pesticide residues and pathogenic risks resulting from improper agricultural and post-harvest handling practices and poor hygienic management in fruit and vegetable chains are the main factors that compromise the safety of horticultural produce. These safety risks are of critical concern in view of their immediate and long term threats to human health. Poor transportation practices and logistical operations in horticultural chains also create a negative impact on quality, resulting in limited market opportunities for fresh produce and thus low levels of income for small farmers and other chain stakeholders.

Nowadays, post-harvest quality and produce safety are considered the most important concerns. There is enormous potential for fruits and vegetables for both domestic and foreign investments if government of Sri Lanka addresses critical requirements such as international safety and quality standards for this industry.

The present status of government registration of agro-chemicals and their impacts on human health is not properly investigated. It appears that fresh fruits and vegetables being consumed by the people could have the levels of residues that far exceeded the Food and Agriculture Organization (FAO) recommended Maximum Residue Limits (MRLs). Therefore, food safety issues need to be exhaustively investigated to know whether the current levels of chemical residues in fruits and vegetables are still below the critical level or exceeded the FAO-recommended MRLs creating detrimental effects on the people. In the recent years, the number of patients with cancer, heart and kidney diseases is sharply increasing as a result of food adulteration and taking a heavy toll on public lives (Morol, 2014 cited in Hassan, 2014). The present study attempts to review the relevant literature, especially in the context of Sri Lanka, in relation to the present status of control of quality and safety of fruits and vegetables in horticultural chains.

1.2 Justification of the Research

The fruit and vegetable sector has been a driving force in stimulating a healthy growth trend in Sri Lankan agriculture. At present, the controlling quality and assuring safety of fruits and vegetables in supply chain has become one of the most challenging issues in Sri Lanka. In the recent past various unscrupulous acts throughout the supply chains by various actors involved were reported. In addition to post-harvest losses, frequent cases of food adulteration with harmful chemicals detrimental to people's health warrant immediate attention of the authorities.

Thus post-harvest losses resulting in quality deterioration and presence of chemical residues in the harvested fruits and vegetables have created significant public outcry. People tend to consume less fruits and vegetables for the fear of the purported harmful attributes contained in them due to those ill practices. Consequently, people encounter under nutrition on one hand due to low intake of fruits and vegetables and dreadful diseases by consuming adulterated food on the other. Therefore, food safety issues need to be extensively investigated to examine the impact of current levels of practices.

1.3 Research Objectives

- To review issues related to post-harvest losses, current measures to minimize and overcome them in fruit and vegetable supply chains
- To review the safety issues related to food adulterations in fruit and vegetable supply chains in the country
- To identify the institutional level measures to minimize quality and safety issues in fruit and vegetable supply chains in the country
- To review success lessons and strategies developed by other countries of the Asia and Asia-Pacific region to mitigate the issues related to quality and safety issues in fruit and vegetable supply chains

1.4 Research Methodology

- Literature review of the studies related to post-harvest losses and safety issues of fruits and vegetable supply chains and studies on minimizing and overcoming post-harvest losses undertaken by different research institutes, Universities in Colombo, Kandy, Anuradhapura, Matara and Makandura (peer–reviewed journals, conference proceedings, white papers and presentations) and conducted in Asia and the Asia-Pacific region.
- Key informant and stakeholder interviews in different government departments, research institutes and Ministries to identify the role of those institutes to maintain quality and safety issues of fruit and vegetable supply chains
- Literature review of the studies related to post-harvest losses and safety issues of fruit and vegetable supply chains and studies addressing to minimize and overcome post-harvest losses in the countries of the Asia and the Asia-Pacific Region
- Summarizing the results from individual studies undertaken in fruit and vegetable sector in Sri Lanka
- A literature survey was carried on research papers from peer–reviewed journals, conference proceedings, white papers and presentations from the industry.

CHAPTER TWO

Fruits and Vegetable Sector

2.1 Introduction

Fruits and vegetables play a vital role in human nutrition, particularly as sources of vitamins, minerals, dietary fibre and antioxidants. Consumption of a variety of fruits and vegetables on a daily basis is highly recommended for the health benefits derived from it.

As a developing Asian country, agriculture is one of the key elements in the Sri Lankan economy. Vegetable and fruit cultivation is a major agricultural activity in Sri Lanka. Next to paddy, the vegetable sub sector is the most prominent in the agriculture sector considering the cultivation distribution and the size of population engaged in. Vegetables grown in Sri Lanka can be broadly classified as upcountry and low country vegetables. The upcountry vegetables include leeks, beans, cabbage, beetroot and carrot, mainly cultivated in hilly areas located in the central part of the country. The low country vegetables are brinjal, ladies finger, bitter gourd, snake gourd, long beans, leafy vegetables, luffa, drumstick, capsicum, which are mostly cultivated in low lands, paddy fields and *chenas* of low country areas. A larger proportion of upcountry vegetables are grown in Badulla and Nuwara Eliya districts. Potato production heavily depends on these two districts. Further, beans, tomato, carrot and leeks are cultivated in those two districts. Matale also has a sizable production. Unlike upcountry vegetables, geological restrictions for producing low country vegetables are minimal. Districts such as Kurunegala, Moneragala, Anuradhapura and Hambantota produce okra, bitter gourd and snake gourd in large quantities whereas the production of other districts is relatively lower. With the conclusion of the war, vegetable production from north and east parts of the country is gradually increasing and the vegetable and fruit production in Sri Lanka has continuously increased during the post war periods. Sri Lanka produces around 710,000 metric tons of vegetables and around 540,000 metric tons of fruits annually. The majority of the population engaged in agriculture is small scale producers or home garden growers whose individual extent of land does not exceed a hectare. The entire local demand for the vegetables is met through local production and only a negligible share has been imported to meet the special demand of tourist hotels. Almost all the production is consumed locally except for one percent that is being exported (Sri Lanka Export Development Board, 2013).

Fruits and vegetables make a significant contribution to food security, nutrition, poverty reduction and steering economic development. Poor quality, safety and high post-harvest losses are major challenges existing in traditional fruit and vegetable marketing chains that feed the mass market in the region with farmers and retailers being the most affected chain stakeholders. Many of the stakeholders associated with fruit and vegetable chains lack basic awareness of the factors that could compromise the quality and the safety of fresh produce during harvesting and post-harvest stages.

2.2 Characteristics of Fruit Sector in Sri Lanka

When considering the fruit sector, commercial cultivation is reported only for a few varieties such as banana, pineapple, papaw, passion fruit and rambuttan. Other fruit varieties such as mango, wood apple, guava, pomegranate and avocado are supplied mainly from home gardens. Moreover, a considerable proportion of supply of banana, papaw, passion fruit and rambuttan is arriving from home gardens as well. The demand for local fruits such as banana, mango, pineapple and papaw is met mainly through local production. Only a very small quantity has been imported to cater to hospitality industry. However, the local demand for certain fruits such as apples, oranges, grapes and dates is met through imports. Types of fruit, popular varieties and major growing areas are presented in the Table 2.1.

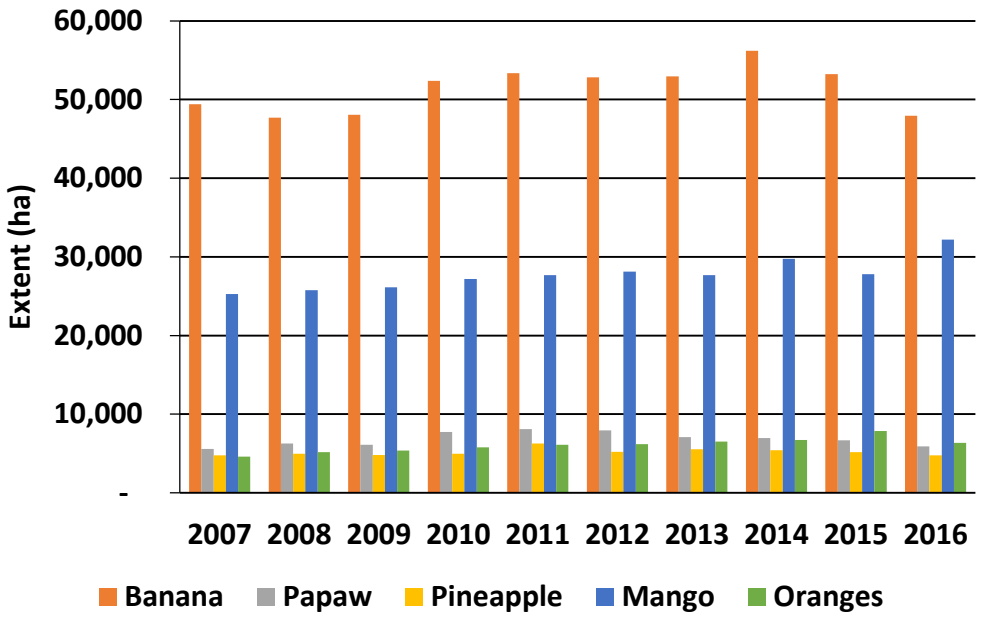
Table 2.1: Major Fruit Varieties and Growing Areas in Sri Lanka

Type	Popular Varieties	Major Growing Areas
Banana	Embun, Kolikuttu, Seeni and Embul	Kurunegala, Ratnapura and Moneragala districts
Mango	Karthakolomban, Villard, Vellaicolomban, Ambalavi, Chembatan, Malwana	Kurunegala, Anuradhapura, Ratnapura, Hambantota, Gampaha and Moneragala
Papaya	Rathna and Red Lady	Kurunegala, Kalutara, Ratnapura, Gampaha, Galle, Anuradhapura, Puttalam, Hambantota
Pineapple	Kew and Mauritius	Kurunegala, Gampaha, Badulla, Puttalam, Moneragala

Source: Department of Agriculture, Sri Lanka (2016-2017)

2.2.1 Extent and Production of Fruits

Banana, mango, pineapple and papaya are the mostly cultivated fruit varieties in Sri Lanka. Banana is the mostly cultivated fruit crop in Sri Lanka and the cultivated extent is around 47,958 ha in 2016. The second highest extent was recorded for mango. Further, variation in extent versus production of certain fruit varieties is depicted in Figure 2.1 and Table 2.2. Considering the total extent of major fruit varieties grown in the country over the last ten years, it was more or less stable with slight fluctuations.



Source: Department of Census and Statistics

Figure 2.1: Cultivated Extents of Major Fruit Varieties in Sri Lanka (2007-2016)

Table 2.2: Production of Major Fruit Varieties in Sri Lanka (2007-2016)

Year	Banana ('000 bunches)	Papaw ('000 No.)	Pineapple ('000 No.)	Mango ('000 No.)
2007	32,419	33,555	44,421	424,701
2008	33,121	38,361	43,480	394,598
2009	31,982	37,320	41,289	411,763
2010	35,776	49,600	44,188	432,903
2011	37,661	52,343	44,429	419,503
2012	39,772	61,484	46,614	394,624
2013	40,097	55,071	39,063	394,573
2014	44,177	62,448	38,582	382,665
2015	56,998	61,345	43,909	424,063
2016	54,395	49,661	40,339	432,755

Source: Department of Census and Statistics

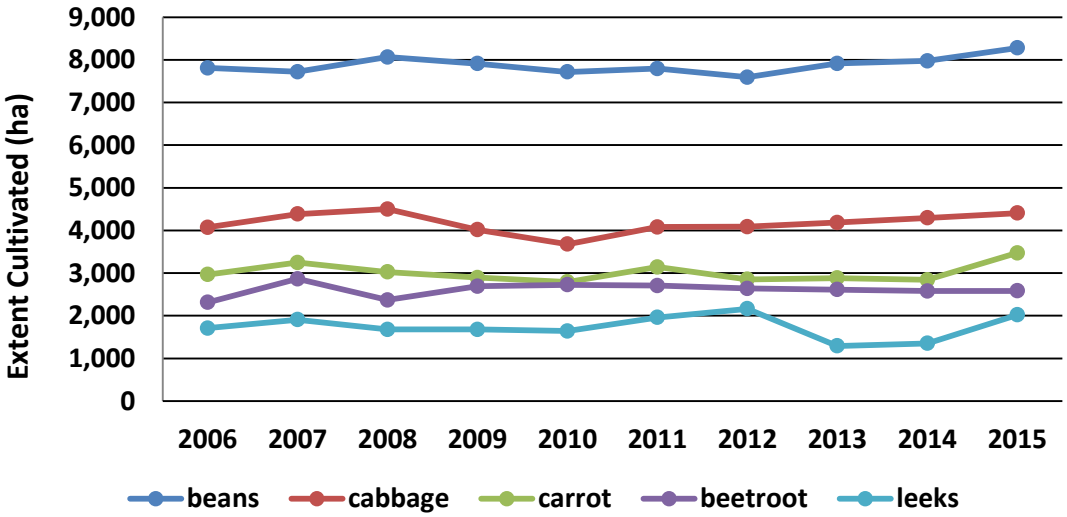
2.3 Characteristics of the Vegetable Sector in Sri Lanka

Besides rice, the vegetable sub sector plays an important role in Sri Lankan agriculture not only because a large number of farmers are engaged in it, but as a main source of dietary nutrition. Of the two main vegetable farming systems the upcountry types (mostly grown in agro-ecological zones such as upcountry wet zone, upcountry intermediate zone, mid-country wet and intermediate zones) constitute vegetables such as beans, carrot, leeks, cabbage, beetroot, raddish and knolkhol. Low country vegetables are traditionally grown on lowlands in that Yala season and shifting cultivation (chena) lands in the dry zone and highlands in wet and

intermediate zones. Major low country vegetables growing in Sri Lanka are brinjal, bitter gourd, capsicum, luffa and okra.

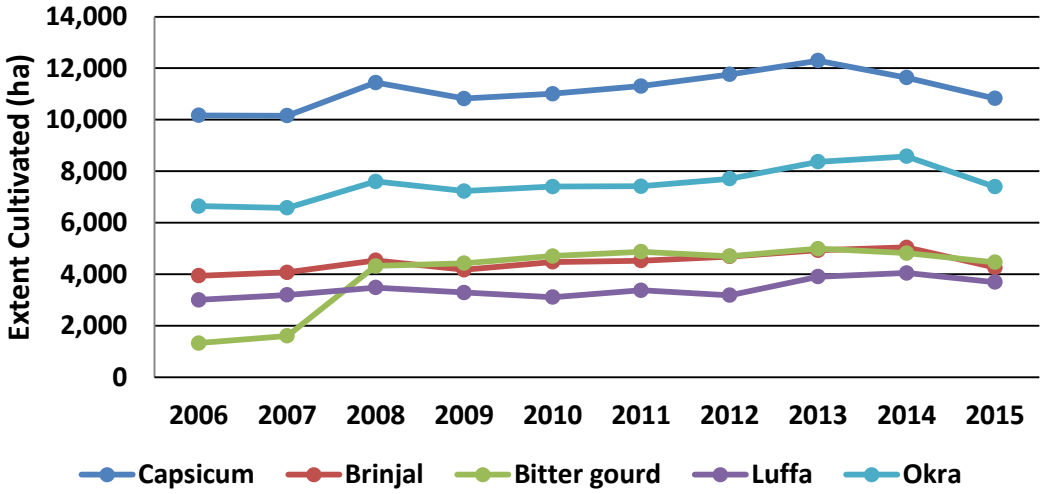
2.3.1 Extent and Production of Vegetables

Variations in both up and low country vegetable extent are depicted in Figure 2.2 and 2.3. However, it is observed, rate of growth in extent remained more or less same for all the vegetables over the last ten years. Further, production has increased in higher rate compared to that of the extent, especially in upcountry vegetables, which signifies the increase in productivity over time. The main reason behind this productivity increase can be attributed to the popularization of high-yielding exotic hybrids after 2003.



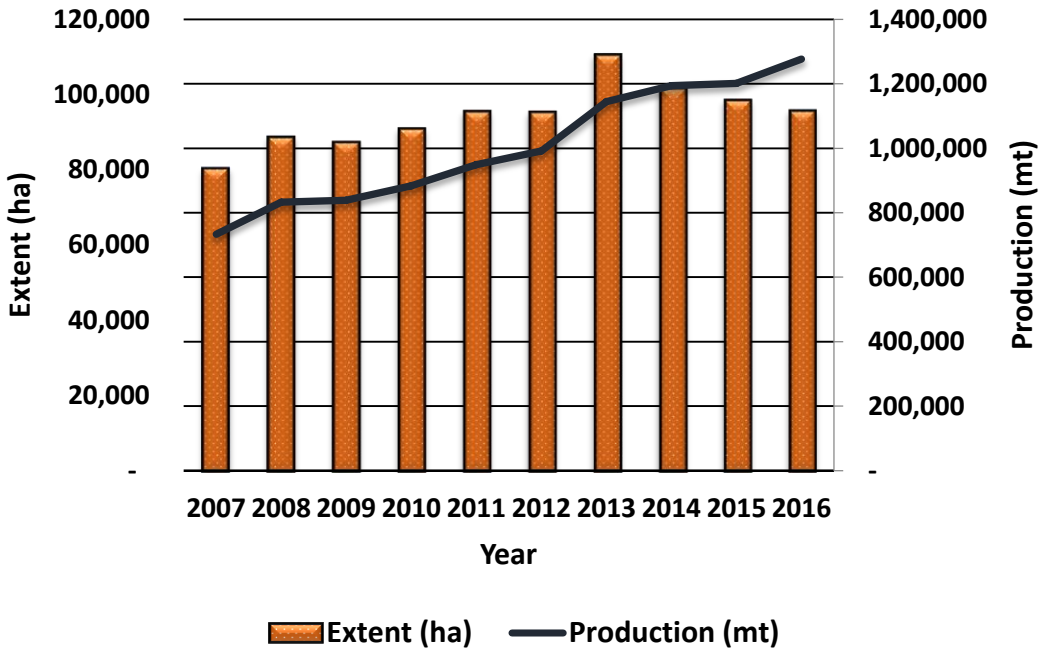
Source: Department of Census and Statistics

Figure 2.2: Variation in Extent Cultivated (ha) - Up Country Vegetables (2006 to 2015)



Source: Department of Census and Statistics

Figure 2.3: Variation in Extent Cultivated (ha) – Low Country Vegetables (2006 to 2015)



Source: Department of Census and Statistics

Figure 2.4: Extent and Production of Vegetables in Sri Lanka (2007-2016)

2.4 Exports of Fruits and Vegetables

Apart from the local consumption, vegetables and fruits are exported to Maldives, United Kingdom, India, Pakistan, Qatar, Saudi Arabia (and other Middle Eastern countries) and Germany. Germany and India are the leading fruit importers of Sri Lanka. Carrot, leeks, cabbage, cauliflower, salad leaves, beetroot, beans, bell pepper, cucumber, pumpkin and bitter gourd are the main vegetables and pineapple, melon, banana, baby jak, lime, dragon fruit and papaya are in the forefront of fruit exports of Sri Lanka (Central Bank of Sri Lanka, 2014). In 2016, 33,000 mt of fresh fruits worth Rs. 5 billion and 21.1 million kilos of vegetables with a value of Rs. 3.9 billion were exported (Central Bank of Sri Lanka, 2016).

Sri Lanka is an emerging contributor of the tropical fresh fruit exports in the Asian region. Table 2.3 shows the export value and quantity (in fresh form) of banana, papaya, pineapple and mango as major fruit crops that contribute to the export earnings.

Table 2.3: Export of Main Fruit Varieties (in Fresh form) by Quantity and Value (2006 to 2015)

Year	Banana		Papaya		Pineapple		Mango	
	Qty (Mt)	Value (000' Rs)	Qty (Mt)	Value (000' Rs)	Qty (Mt)	Value (000' Rs)	Qty (Mt)	Value (000' Rs)
2006	58	11,227	113	23,711	1,752	148,284	40	16,776
2007	855	51,568	197	35,369	1,513	190,298	90	60,980
2008	1,751	87,558	800	97,580	1,488	188,909	43	27,238
2009	2,657	114,792	454	53,601	1,254	139,149	62	25,085
2010	5,048	212,545	783	82,831	798	116,991	103	27,935
2011	10,116	416,508	668	80,254	704	99,328	79	28,739
2012	16,218	775,618	1,188	98,928	346	48,589	25	13,469
2013	19,358	1,063,213	1,644	150,403	1,270	208,440	34	20,127
2014	19,166	2,010,806	3,229	241,727	1,982	357,024	134	28,627
2015	19,025	2,159,259	2,767	259,679	1,454	285,082	67	39,051

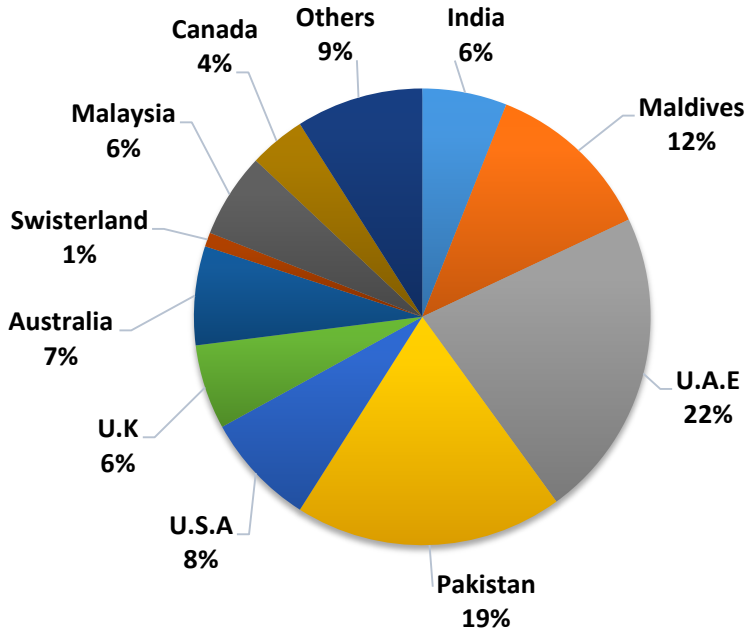
Source: Department of Customs (2006-2015)

Contribution of agricultural exports to the total export earnings in 2013 and 2014 was 23 percent and 23.8 percent respectively (EDB, 2013). However, contribution of vegetable exports to the agricultural export earnings remains less than one percent. There was a rise in real export value of vegetable exports from Rs. 7 million to Rs. 15 million (inflation adjusted) during 1990-2012 (Central Bank of Sri Lanka, 2013). However, export of processed vegetables decreased to Rs. 5 million in 2012, from Rs. 13 million value reported in 1990, mainly due to the collapse of gherkin forward contract. As at 2013, major export destinations of Sri Lankan vegetables were U.A.E as 22 percent, followed by Maldives as 12 percent and Pakistan as 19 percent (EDB, 2013) (Figure 2.5).

Table 2.4: Vegetable Export Data (Fresh and Chilled)

Year	Quantity (mt)	Income (USD million)
2010	13,539	16
2011	13, 062	19
2012	11,138	15
2013	15, 627	20
2014	20, 223	25

Source: Export Development Board (2015)



Source: Export Development Board, 2015

Figure 2.5: Major Export Destinations of Vegetables

Produce collectors operating at the village level collect the production from several small farmers to bring up adequate volume before handing over to the transport agents of the exporters. Normally leading exporters have their own transport agents who supply the produce at the exporter's store at the correct time (at least 10-12 hours before the flight). Transport agents are aware of the exporter's buying price, before collecting. Alternatively, especially when in short supply, the exporters go back to the traditional system of buying from the Colombo Wholesale Market (Manning market). At the wholesale market, though no sorting or grading would take place, a special charge of around Rs. 2.00 per kilo is charged for good quality produce (on superficial analysis). Additional Rs. 6.00 per kilo is charged by the broker. Sorting and grading take place at the exporter's store; however, at times the broker may also sort and grade for the exporter. Even in this channel of marketing, there is no improvement in post-harvest losses which amount to almost 30 percent (Dias, 1994).

A survey conducted by the Ceylon Chamber of Commerce identified few issues faced by the exporters regarding the quality and safety of fruits and vegetables as described below (Gunaruwan and De Silva, 2014);

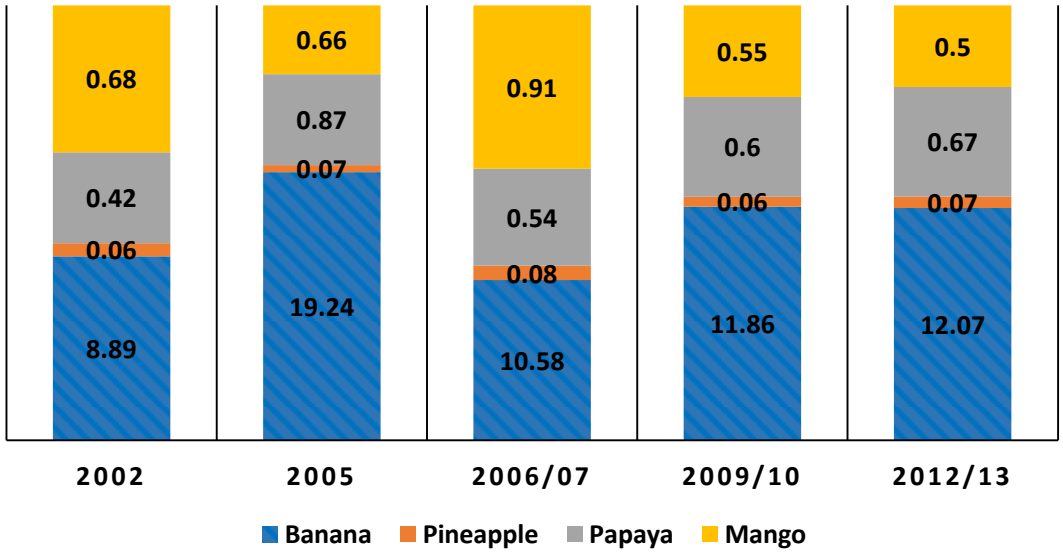
- Due to lack of knowledge on standards on the application of agro-chemicals and pesticides, farmers apply them in excess affecting food safety and polluting waterways
- High post-harvest losses compared to the competitor countries
- Lack of extension services of the DOA. The exporters have to advise their out-growers using their staff

- Lack of good quality seeds for cultivation
- Lack of laboratory facilities to carry out testing in the country
- Lack of domestic certification institutes to provide internationally accredited organic certification

2.5 Consumption of Fruits and Vegetables

2.5.1 Per Capita Consumption of Fruits (Banana, Pineapple, Papaya and Mango)

Monthly per capita consumption of all fruit categories is much lower than the requirement. As shown in Figure 2.6, per capita consumption of banana is much higher than other three types of fruits.



Source: Department of Census and Statistics

Figure 2.6: Per Capita Consumption of Banana, Pineapple, Papaya and Mango per Month

In the given time period per capita consumption of banana has varied from 8.89 in 2002 to 12.07 in 2012/13 period. Pineapple is the least consumed fruit by the Sri Lankans when compared to other three types of fruits indicated in the Figure 2.6. The monthly per capita consumption of pineapple has been relatively stable during the period. Per capita consumption of papaya per month has been more constant over the years. Although papaya is one of the healthiest fruits available throughout the year per capita consumption is much lower.

2.5.2 Per Capita Consumption of Vegetables

As per the food based dietary guideline for Sri Lankans, at least nine table spoons of cooked vegetables or three cups of raw vegetable salads a day was required for a person. However, the per capita intake of vegetables (leafy vegetables + both low and upcountry vegetables) by a Sri Lankan was around 114/g per day (Ministry of Agriculture, 2015).

Table 2.5: Vegetable Consumption (Average Monthly per Person) of Main Up and Low Country Vegetables – Sri Lanka (2012/13)

Type	Name	Consumption (g)/month
Up Country	Beans	325.63
	Carrot	139.22
	Beetroot	107.73
	Cabbage	158.49
	Leeks	85.49
Low Country	Brinjal	263.59
	Okra	117.86
	Bitter gourd	73.34
	Luffa	81.14
	Capsicum	49.1

Source: Department of Census and Statistics, 2015

2.6 Marketing Channels of Fruits and Vegetables

With the population increase, the demand for fruits and vegetables also increases. To meet such demand and provide food in proper quality and nutrition, supply chain plays a very vital role in this sector and becomes even more important because of perishable nature and very short shelf life. It not only helps cut costs, but also adds to maintain and improve the quality of produce delivered which are perishable in nature (Veena and Venkatesha, 2011). Owing to the very short shelf life and perishability, these items require proper transportation, handling and storage facilities to preserve freshness till it reaches the consumer. It also manages the relationship between business responsible for the efficient production and supply of fresh products from farm level to ultimate consumers, to reliably meet the requirements of the customer in terms of quality, quantity and price.

There are several players involved in fulfilling the needs of the consumer in the supply chain management of fruits and vegetables such as farmers, local traders, transporters, processors and retailers. Perishable food produced in the farmer's field reaches the end consumer through a chain of intermediaries. These intermediaries carry out various functions, such as transfer of ownership of commodities, its movement, maintenance and preservation of quantity and quality, payment to the seller and commodity delivery to the buyer (Halder and Pati, 2011). All the links from farmers to end user of the commodity constitute supply chain of the agricultural commodities.

When considering the marketing channels of fruits and vegetables in Sri Lanka, there was a change observed during recent past after establishing the regional wholesale markets known as economic centres. At present, a considerable portion of fruits and vegetables is brought to the regional wholesale markets and from there the commodities are directly supplied to the consuming areas. Before introducing the concept of Dedicated Economic Centres, the Manning market managed the entire vegetable and fruit harvest distribution throughout Sri Lanka. Currently, 12

Dedicated Economic Centers in Sri Lanka act as wholesale markets, namely; Thambuththegama, Nuwara Eliya, Keppetipola, Welisara, Veyangoda, Narahenpita, Embilipitiya, Meegoda, Piliyandala, Dambulla and Ratmalana. Still the Manning market in Colombo acts as the wholesale market for fruits and vegetables to Colombo and many other regions. Traders and farmers throughout the island daily visit the Manning market with their harvests. Apart from the Manning market, there are 18 other relatively large markets located in Colombo city limits including the markets in Maradana, Grandpass, Dematagoda, Borella, Wellawatta and Kirulapone. Unlike the Manning market, these markets are largely engaged in retail sale of vegetables and fruits purchased from the Manning market (Priyadarshana, 2016).

Wide seasonal fluctuations in production with a peak in January to March and a lean period in May to June is a predominant feature of the supply chain for fresh fruit and vegetables in Sri Lanka. Inadequate storage facilities lead to surpluses during the harvest period and extreme shortages during the off-season. The system therefore exhibits wide seasonal price variations. 5This situation is more evident in the case of fruits. During the peak supply season, the fresh fruit and vegetable supply system typically records a wastage of around 30 to 40 percent. Prior to the introduction of economic liberalization policies in 1980s, the fresh fruit and vegetable marketing system in Sri Lanka was dominated by state sector interventions including the operation of commodity marketing boards, purchasing mechanisms and other interventions. This period was typically characterized by: (i) high levels of production and price risks faced by producers, (ii) the presence of multi-layered and long marketing chains, (iii) poor product quality at the retail end with little or no choice, and (iv) high price uncertainty for the consumer.

Marketing channel is a chain of middlemen involved in the process of selling of different vegetables at different stages. Figure 2.7 shows types of marketing channels indicating that how vegetables move from the producer to the end consumer. The bulk of the marketing is carried out by commission agents and large scale traders of the private sector. The chain of intermediaries begins with the village level collecting agents and the most usual marketing channel is the farmer-assembler-wholesaler-retailer-consumer systems. However, the flow follows different channels depending on the distance of the market to the producing area involving more intermediaries.

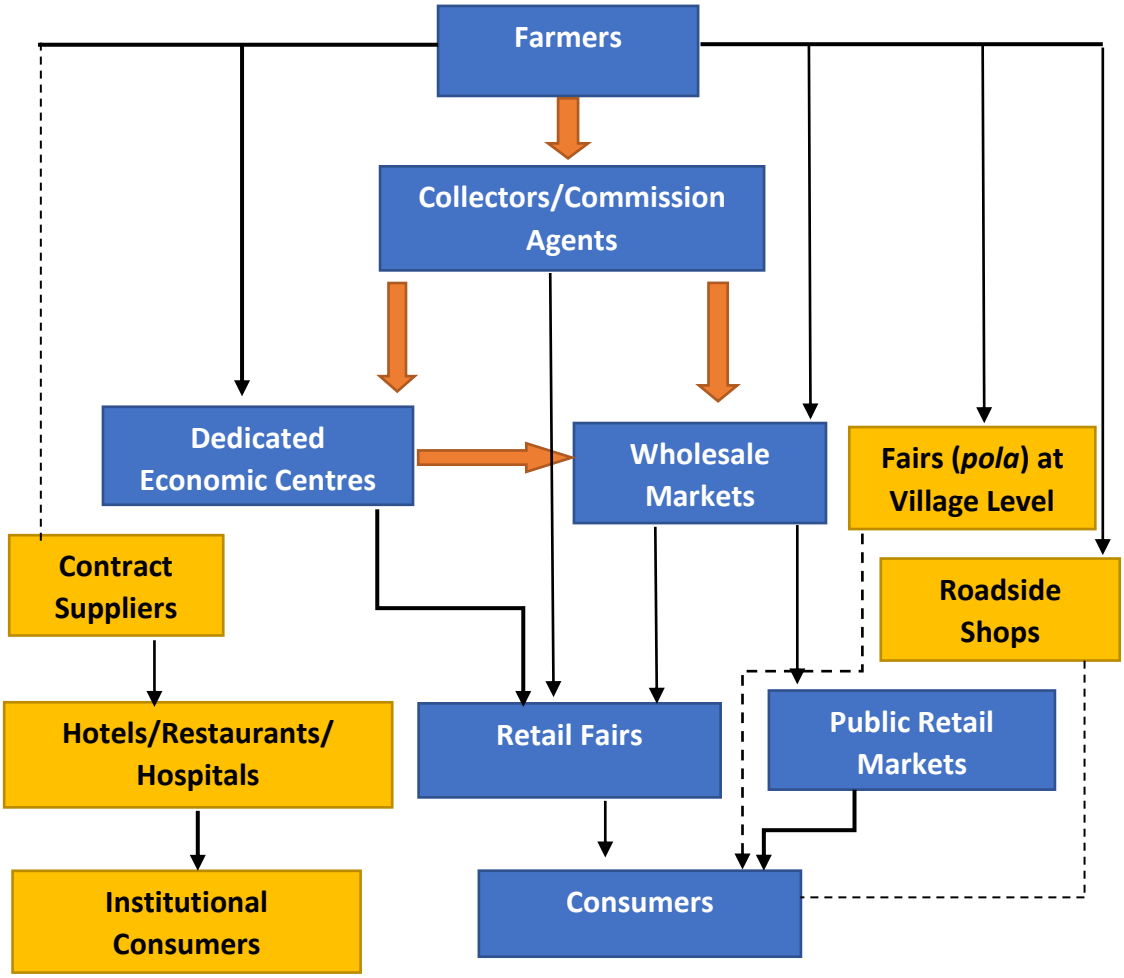
In a country like Sri Lanka where food production is in the hands of small producers, a large number of intermediaries are engaged in food supply and distribution activities. Over 90 percent of food supply and distribution is handled by the private sector. Temperate vegetables, mainly grown in the hill areas are sent directly by framers to commission agents in the Manning market Colombo through organized transporters. Meanwhile, collectors purchase tropical vegetables from farmers at weekly fairs (*pola*) to send them to the same market. Wholesaling facilitates the economic function of buying and selling by allowing the forces of supply and demand to converge and establish a single price for a commodity. The people engaging in wholesaling can act as merchants, buying and selling the produce, brokers dealing in

orders rather than goods, commission agents acting for the producers or export/import agents that only deal in foreign trade.

Traditional marketing channels for vegetable sector differ substantially from the supermarket supply chains. The traditional distribution system for fresh vegetables in Sri Lanka still controls more than 90 percent of the vegetable sales. A large number of participants engaged in the conventional marketing channels for vegetables perform various activities such as assembling, sorting, packing, transporting and selling. The traditional vegetable supply chains in Sri Lanka are illustrated in Figure 2.7. However, each marketing channel does not behave in the same manner all the time which does not imply its availability for all farmers at all times. The marketing channels are very few in the areas where road conditions are poor and the production is limited (Rupasena et al., 1999). Generally farmers sell their vegetables to vegetable collectors or send them to commission agents at the wholesale markets through transporting agents. Most of the farmers in main producing areas bring their vegetables directly to the Dedicated Economic Centres. The commission agents tend to quote a price to the farmers, which is lower than the price for which the vegetables are actually sold at the wholesale market. Thus, the commission agents seem to exploit the farmers. This is rampant in the Colombo wholesale market (Perera et al., 2004).

In conventional vegetable supply chains scant attention is paid to the quality of the produce by participants in the chain. In the traditional vegetable supply chains, quality signals are not passed down to the farmers. Farmers are paid by the weight of produce and quality is not taken into account. This has led them focus on increasing the weight while tempting them to indulge in nefarious acts to increase profit such as stacking stones and inferior quality vegetables in the middle of the sacks of vegetables (Rupasena et al., 1999; Perera et al., 2004).

In conventional marketing channels, transporting agents packed vegetables tightly in the polysac bags or in net bags and they overload those sacks in transporting vehicles resulting in high wastage of vegetables (Rupaseana et al., 2001).



Source: Vidanapathirana, 2008

Figure 2.7: Traditional Vegetable Supply Chains in Sri Lanka

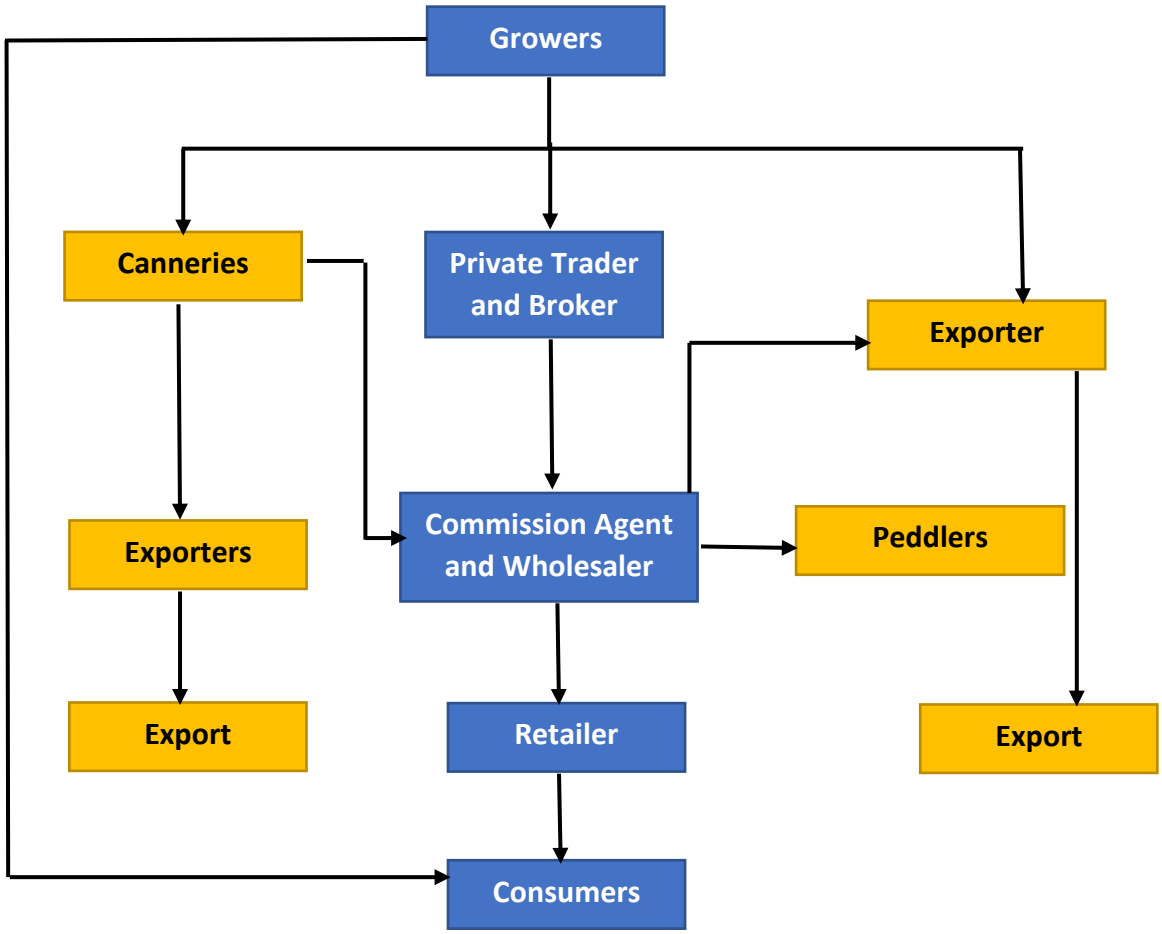


Figure 2.8: Marketing Channel Flow Chart for Fruits in Sri Lanka

2.6.1 New Partners in the Emerging Fresh Fruit and Vegetable Supply Chains

Adoption of economic liberalization policies in the 1980s gave rise to significant changes in the fresh fruit and vegetable marketing system. Policy changes enabled private sector entrepreneurs and institutions to play an increasingly dominant role in improving supply chain management and the structure and performance of the fresh fruit and vegetable production and marketing system. The change was further supported by a number of factors including increasing per capita incomes, expanding urbanization, shifting food preferences and consumption patterns and improved communication facilities. New supply chain partners have emerged including outgrowers, private sector extension workers, transport operators with refrigerated trucks and modern packaging systems, warehouse operators and integrators at the intermediary level, supermarkets, retail shops and exporters.

2.6.2 Supermarket Channels

Supermarkets not only change the way we shop, but also radically change food supply chains and producer-retailer relations through new procurement practices.

Supermarkets have increasingly become stronger players in fruit and vegetable retailing. Their thrust is on securing a steady flow of quality products that match the consumer preference while being available at a competitive price. Recognizing the importance of selling fresh food in order to attract customers, the modern supply chains have made significant progress in improving their supply and display of fresh products. The logistics of fresh product supply are much more complicated than that of dry goods and as a result supermarket chain takes much longer time to organize. The supermarkets are competing to adopt a range of management strategies to offer superior quality products, a wider choice, reduced wastage, greater value for money and shorter and more effective supply chains (Abeysekera and Abeysekera, n.d.).

Supermarkets are more selective in their purchasing and expect better quality fruits and vegetables. Farmers supplying to supermarkets receive a higher price compared to the other farmers and a study on marketing vegetables through the supermarkets shows that farmers in proximity to the collecting centres and having satisfactory transport networks are motivated to sell their produce to the supermarkets due to higher price. In traditional markets superior quality is not rewarded.

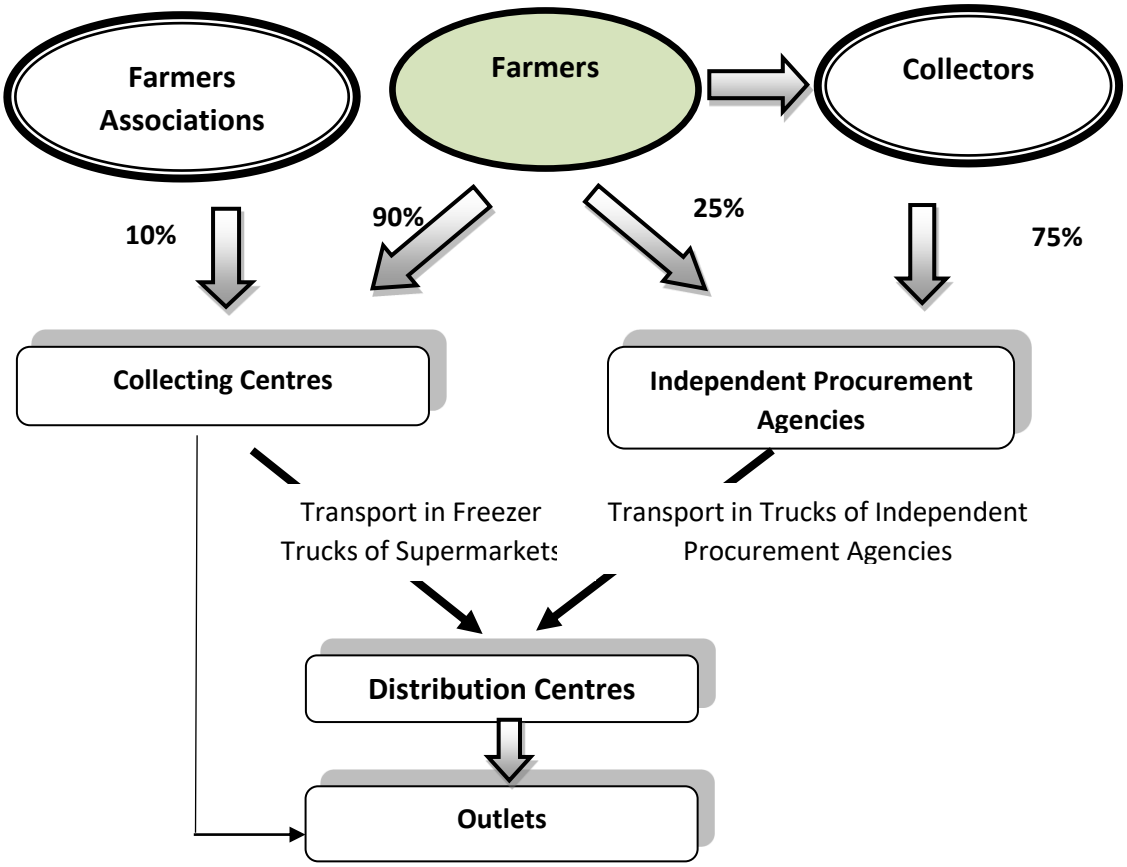
However, despite the recent expansion in the retail chains their share of vegetable market is reported to be only around five percent. Hence they do not procure large quantities and the farmers supplying to these chains have to find alternative suppliers for the remainder of the produce. Having their own collection centres and selective suppliers also reduce the time taken for the F&V to move from the farmer to the supermarket (within 24 hours) which helps retain the freshness of the produce and on the other hand lower number of intermediaries reduces the costs and post-harvest losses. The main supermarkets do not have additional reserves of F&V but observe daily purchasing system.

Most of the supermarkets in Sri Lanka use a combination of various procurement schemes. Cargills, Keells Super and Laugfs Sunup have distribution centres (DC) in Colombo. The retail outlets prepare their orders for the following day based on the day's sale. At the end of the day, all outlets report to their distribution centre about their vegetable demands (quantities and varieties) for the following day. After DCs' summary and integration of these demand numbers, their suppliers or collecting centres are informed of the requirement. The leading supermarkets (with a large number of outlets) have vegetable collecting centres at major producing areas to procure their vegetable requirements. In addition, they procure vegetables from independent procurement agencies. Collecting centres procure vegetables directly from farmers or farmer associations, while independent procurement agencies procure directly from farmers or collectors. The vegetable requirements of the supermarket are conveyed to these regional vegetable collecting centres or to independent procurement agencies and accordingly vegetable orders are issued to the farmers and the vegetable collectors.

The quality parameters actually adopted are mostly related to the physical attributes of the produce such as size, colour, texture and non-existence of pest and disease attacks. The product that does not meet the standard is not paid and disposed of.

What is held back from delivery by the supplier is typically sold in secondary markets such as traditional wholesalers. The selected vegetables are loaded into standard crates belonging to the supermarkets. From each collecting centre and independent procurement agency, vegetables are transported to the distribution centres in freezer trucks or by trucks with no freezing facilities. At the distribution centres workers sort out the bulk vegetables, clean them and package them. From the distribution centre, vegetables are dispatched to individual outlets in Colombo and suburbs either in freezer trucks or non-freezer trucks. For other outlets, vegetables are dispatched directly on the way to Colombo from collecting centres.

Direct purchase from farmers permits more rapid movement of produce from farm to collecting retail outlets, enabling supermarkets, to sell the fresh produce. It was observed that time gaps between collecting from farmers' field to outlets is less than 24 hours. Though the emergence of supermarkets is significant in Sri Lanka, the quantity of vegetables moving along these supermarket supply chains is comparatively insignificant compared to traditional chains. Specially, in relation to fresh vegetable retailing, supermarket share in Sri Lanka is far behind that of the other product categories, which is as low as five percent. Supermarkets are currently rapidly growing in urban and suburban areas in Sri Lanka.



Source: Vidanapathirana, 2008

Figure 2.9: Procurement and Distribution of Vegetables by Leading Supermarkets in Sri Lanka

2.7 Fruit and Vegetable Industry in Sri Lanka

The fruit and vegetable industry in Sri Lanka can play a critical role in commercialization of non-plantation agriculture. The industry purportedly develops backward linkages towards small farmers, thereby accelerating crop diversification in the paddy dominated non-plantation agriculture sector. Moreover, fruits and vegetables are considered potential candidates for the diversification and commercialization of peasant farming in Sri Lanka (Dunham, 1995; cited in Esham and Usami, 2006).

Sri Lanka's F&V industry comprises processors, exporters of fresh and processed fruits and vegetables and the market intermediaries particularly supermarket chains where a certain amount of value addition takes place. Majority of the fresh fruit and vegetable exporters and processors can be classified as small and medium scale industries.

2.8 Issues in Fruit and Vegetable Supply Chains in Sri Lanka

Vegetable and fruit supply chain has always been a contemporary topic, creating news in media, academia and state institutes in Sri Lanka. Vegetable price fluctuations, excess supply and wastage are the most common and recent issues that are frequent in vegetable and fruit supply chains. It is also proved that this is a common issue for a majority of developing countries including Sri Lanka.

1) Fragmentation Issues

One of the main issues in the supply chain of fruit and vegetable sector in Sri Lanka is the large number of local traders and intermediaries who grab the lion's share of farmer's income. The whole supply chain in Sri Lanka is dominated by local traders.

2) Integration Issues

Linkage and integration between various players in the supply chain plays a very important role to make the whole supply chain effective and profitable. But in the supply chain of F&V sector in Sri Lanka lack of forward and backward integration persists between the farmers and the other partners.

3) Infrastructure Issues

Supply chain infrastructure plays an important role in the F&V sector. Appropriate and adequate infrastructure helps farmers and agri-businessman to operate their business successfully and helps deliver the goods in the right time in the right condition. In Sri Lanka, infrastructure is the main impediment in the supply chain of agricultural products causing high amount of losses.

4) Packaging Issues

Packaging is very important for F&V considering its highly perishable nature. Proper packaging is vital to maintain their shelf life. High cost of packaging material is a major impediment for the farmers to do proper packaging of their goods.

5) Technological Issues

Technology is surrounded by many issues: advancement issues, inefficiency and old machinery. Due to these concerns it has become difficult for the farmers and agri-businessman to use appropriate technologies and techniques to minimize post-harvest losses and time in operational activities.

6) Farmers' Awareness

Farmers have very poor knowledge on the use of latest technologies and techniques to work effectively and efficiently. Their knowledge on the management of post-harvest produce and quality of seed is also minimal. Poor awareness level of the farmer may hinder the efficiency of the supply chain of F&V.

7) Quality Issues

Quality is a very important factor in food industry/sector since it directly relates to the health of the people. It is vital for supply chain to deliver the fresh goods in a timely manner while maintaining quality standards to the customer. A well-formed supply chain helps maintain the shelf life of produce while preserving the quality. Quality has a strong impact on the supply chain; leads to efficiency and less rejection by the customer. Sri Lanka is plagued with below par quality standards, which has become a stumbling block to reach the export market apart from other issues such as poor hygiene and safety standards and quality degradation.

8) Processing and Value Addition Issues

Processing and value addition is a way to increase the shelf life of food produce and reduce the losses. High amount of food processing may lead to low wastage of fruits and vegetables. It opens doors for the processed food to reach various destinations. However, in Sri Lanka food processing remains at a low level as compared to other countries and on the flip side value addition occurs at minimum scale due to lack of processing units and processing units being located far apart.

9) Financial Issues

Income of farmers remains low as they are not paid a fair price for their produce and intermediaries grab most of the returns. The difference between the final consumer price and farmer’s return is very high. Lack of transparency in pricing prevails as a result of farmer being deprived of a fair price for the produce.

10) Post-harvest Loss Issues

Post-harvest losses are a major problem in the supply chain of fruit and vegetable sector in Sri Lanka. Huge amount of losses are recorded in the supply chain of perishable food in reaching the main market and processing units. Around 30 – 40 percent of total food produce is wasted. Heavy losses were incurred during transportation and storage of fresh food produce.

CHAPTER THREE

Review of Post-harvest Handling, Losses and Current Measures to Minimize and Overcome Losses in Fruits and Vegetable Supply Chains

3.1 Introduction

Post-harvest losses can be largely attributed to poor organization, improper handling, transportation and packaging, poor storage and weak rural infrastructure which result in seriously low returns to producers and reducing the net availability of these commodities in the local market. An underlying cause of these losses is limited awareness of stakeholders in fruit and vegetable supply chains. Spoilage of fresh produce is also accelerated by the hot and humid climate in the country.

Both quantitative and qualitative losses occur in fruits and vegetables between harvest and consumption. Qualitative losses such as loss in edibility, nutritional quality, caloric value and consumer acceptability of fresh produce, are much more difficult to assess than quantitative losses. Post-harvest losses vary greatly across commodity types based on the location of production and the season of production.

Post-harvest losses create a negative impact on the economic benefit derived from vegetable production. Despite the high significance attached to vegetables in the human diet they are of highly perishable nature. Losses between farms and consumers are highest in developing countries where lack of knowledge, skills, technologies, techniques and facilities for produce handling and processing is more prominent. This loss of nutritious food and economic opportunities contributes to poverty, unemployment and malnutrition (Acedo and Easdown, 2015). In Sri Lanka, about 16-40 percent of the total production of vegetables (565,250 metric tons from 110,960 ha) is wasted after harvesting (Bamunuarachchi et al., n.d.; Warushamana, 2011; cited in Acedo and Easdown, 2015). Poor packaging and transportation were the leading causes along apart from lack of proper storage. Annual loss in volume is 270,000 mt amounting to Rs. 9 billion.

3.2 Causes of Post-harvest Losses

3.2.1 External Factors

3.2.1.1 Mechanical Injury

Fresh fruits and vegetables are highly susceptible to mechanical injury owing to their tender texture and high moisture content. Poor handling, unsuitable packaging and improper packing for transportation are the causes of bruising, cutting, breaking, impact wounding and other forms of injury in fresh fruits and vegetables.

Four different causes of mechanical injury can be identified: cuts, compressions, impacts and vibration rubbing. Careful harvesting and subsequent handling of the

produce will eliminate most of the risks associated with cutting and wounding of produce.

3.2.1.2 Pest and Diseases

Invasion of fruits and vegetables by fungi, bacteria, insects and other organisms is a major cause of post-harvest losses in fruits and vegetables. Microorganisms readily attack fresh produce and spread rapidly, owing to the lack of natural defense mechanisms in the tissues of fresh produce and the abundance of nutrients and moisture which supports their growth. Control of post-harvest decay is increasingly becoming a difficult task, since the number of pesticides available is rapidly declining as consumer concern for food safety is growing.

3.2.2 Internal Factors

Physiological Deterioration

Fruit and vegetable tissues are still alive after harvest, hence continue their physiological activity. Physiological disorders occur as a result of mineral deficiency, low or high temperature injury or undesirable environmental conditions such as high humidity. Physiological deterioration can also occur spontaneously owing to enzymatic activity leading to over ripeness and senescence, a simple ageing phenomenon (Choudhury, 2006).

Table 3.1: Causes of Loss at Different Points of the Supply Chain

Level of Transport	Causes of Loss
Production/Planning	Poor information Poor production planning Weak credit and price policies Weak institutions Poor services Poor planning marketing/storage facilities Poor road development Inappropriate marketing policies
Pre-production	Lack of information Poor managerial ability Poor roads Low level of technical knowledge Poor quality planting material Poor locations of nurseries
Production	Poor cultural practices Pest and disease damage Ecological and soil conditions Poor water management Physiological damage Mechanical damage
Harvest	Wrong time for harvest Climate damage Physiological damage Mechanical damage
Transport	Environmental conditions Physical and mechanical damage Physiological damage
Assembly/Sorting/Packing	Improper post-harvest handling Delays Physical, mechanical and physiological damages Lack of infrastructure Inappropriate technologies
Transport	Delays Poor coordination Poor technology
Storage	Physical, mechanical or physiological damage caused by rough handling, bacteria, fungus, mildew, insects or rodents and environment
Processing	Physical, mechanical or physiological damage Inefficiencies Poorly trained workers Inappropriate technology
Distribution	Deficiencies in organization, transport, storage, management, technology, training Consumer habits Public sector involvement

Source: LaGra, 1990

Table 3.2: Main Causes of Post-harvest Losses in Different Product Groups

Product Group	Types of Fruits and Vegetables	Causes of Post-harvest Losses
Root vegetables	Carrots, beets, onions, garlic, potatoes, sweet potatoes	- Mechanical injury and improper curing - Sprouting - Water loss and decay - Chilling injury
Leaf vegetables	Lettuce, chard, spinach, cabbage, spring onions	- Mechanical injury - Water loss and decay - Relatively high respiration rates - Loss of green colour
Flower vegetables	Cauliflower, broccoli	- Mechanical injury - Water loss and decay - Discolouration - Abscission of florets
Immature fruit vegetables	Cucumbers, squash, eggplant, peppers, okra, snap beans	- Bruising and other mechanical injury - Water loss and decay - Over-maturity at harvest - Chilling injury
Mature fruit produce	Tomatoes, melons, bananas, mangoes, apples, grapes, cherries, peaches, apricots	- Bruising and other mechanical injury - Water loss and decay - Over-ripeness at harvest - Chilling injury

Source: UNCTAD, 2007

3.3 Post-harvest Losses in Fruits and Vegetables in Sri Lanka

Fresh fruits and vegetables are termed perishable commodities for their inherent tendency for spoilage for physiological reasons. Post-harvest losses can occur at any point between harvest and consumption in the marketing process. Due to tropical and subtropical climates, a variety of fruits and vegetables are grown in Sri Lanka. Unfortunately, a considerable proportion of the harvested produce never reaches the consumers mainly because of post-harvest losses.

The principal reasons for post-harvest losses are: (i) physiological and biochemical processes i.e. increase in the rates of respiration, ethylene production and transpiration loss of water, (ii) microbial decay, (iii) high perishability and (iv) sub-standard post-harvest handling infrastructure.

When a harvested produce reaches the consumer a certain portion of it is lost due to weight lost, mechanical damage, post-harvest diseases and senescence. The quantity lost is referred as post-harvest loss. Post-harvest losses in developing countries are

reported to be excessively high ranging from 20-40 percent, while the value for developed countries remain around 10 percent or less.

Reasons for post-harvest losses in Sri Lanka

- Lack of awareness in correct harvesting handling, packaging and transportation practices
- Lack of properly developed roads specifically at rural level
- Lack of suitable vehicles that are modified for transportation of fresh produce
- Poor protection of the harvested produce from sun and rain
- Poor access to market information

Source: IPHT, 2012

According to Dharmasena and Sarananda (2012), 97 percent of the fruits and vegetables in Sri Lanka are handled through the conventional distribution chains in which agricultural produce is channeled through economic centres with the involvement of middlemen using improper handling practices. Cuts, vibrations, abrasion, compression and impacts are the main causes of mechanical damages to produce during handling and transportation. Compression damage occurs when fruits are over loaded and usually the weight of the load is supported by the product than the container in most of the fruit handling systems. Vibration damage is prominent in vehicles fitted with steel leaf-spring-suspension systems (Vigneault et al., 2009; cited in Wasala et al., 2015).

Jayalal (2015) claims that annually, Rs. 25 billion is wasted due to poor packing and improper transportation. About 20-30 percent of fruits and vegetables go waste while another 10 percent is discarded, as they do not meet the standard sizes. As Jayalal (2015) explains lorries can only hold 5,000 kg of vegetables, but are leading to massive spoilage.

According to Ilangakone et al., (2015), it was reported that post-harvest losses occur due to malpractices committed by farmers and transporters. Compressed packing of vegetables into poly-sack bags, travelling seated on the top of vegetable loaded sacks, poor use of proper containers for transporting are the main reasons for the losses.

Herath (2005) in a study with factors causing post-harvest quality losses in vegetables at the Dambulla DEC reported that post-harvest losses associated with DEC are not much apparent due to the short time taken to transaction (6-10 hours). When the distance of transport to the DEC is high, losses are high. The losses occur mostly after the vegetables pass into the hands of the wholesalers. It was also noted that as the farmers do not sell to the same dealer on a regular basis, opportunities for the provision of feed-back on quality is minimal. Further, when loading and unloading, the loaders do not handle packages well.

Table 3.3: Step-wise Post-harvest Losses of Produce throughout the Harvesting Chain

Crop	Post-harvest Losses (%)				
	Producer	Collector	Wholesaler	Retailer	Total
Fruit					
Banana	2	4	8	6	20
Papaya	6	10	20	10	46
Pineapple	2	4	8	4	18
Lime	4	8	16	12	40
Avocado	2	12	5	22	41
Vegetables					
Beans	4	6	13	7	30
Carrot	3	6	12	4	25
Leeks	5	6	12	7	30
Cabbage	4	7	9	5	25
Tomato	5	10	15	10	40
Okra	3	10	13	20	46
Brinjal	2	5	6	7	20
Capsicum	6	7	10	12	35

Source: Sarananda, 2005

Karunagoda et al., (2011), have measured post-harvest losses for up-country vegetables at different stages of the supply chain as depicted in the Table below.

Table 3.4: Post-harvest Losses of Up-country Vegetables in Sri Lanka

Up-country Vegetables	Post-harvest Losses (%)			
	Producer Level	Retailer Level	Consumer Level	Total
Beetroot	34	37	29	21
Beans	33	43	24	15
Tomato	26	52	22	24
Leeks	28	40	32	27
Carrot	42	41	17	22
Cabbage	25	59	15	23

Source: Karunagoda et al., 2011

3.3.1 Post-harvest Losses in Vegetables

Vegetable commodities continuously change after harvest until completely deteriorated due to live tissues. These changes influence the colour, flavour, appearance, texture and the nutritive value. Harvesting of vegetables at an over mature stage is a common practice in Sri Lanka. Post-harvest losses in okra, beans, long beans and bottle gourds are extremely high owing to the toughening of texture. High temperatures in growing areas and temperature build up during transportation in polypropylene sacks accelerate the toughening process.

Ranathunga et al., (2009) in a study with post-harvest losses of upcountry vegetables found that at producer level, post-harvest loss is 9.29 percent and highest in beetroot (20%) due to fungal attacks, pest attacks including rats. At retailer level, post-harvest loss is 12 percent and minimum is recorded from beans (8%). Post-harvest loss of cabbage and leeks is mainly due to the removing of outer leaves to keep freshness. At consumer level, that is eight percent and highest in beetroot (13%) and lowest in beans (5%).

With regard to carrot, mechanical damage, harvesting time, stress conditions and exposure to high ethylene releasing fruits and vegetables lead to a 30-40 percent loss and therefore, should not be mixed with ethylene releasing fruits and vegetables and should not be exposed to high moisture conditions which permit soft rot (Shirangika et al., 2006).

Tomato are especially vulnerable to post-harvest loss due to their highly perishable nature and to a combination of factors such as pre-harvest diseases and inefficient post-harvest handling procedures. In tomato, pre-harvest diseases such as pod borer attack and blight, over ripening and poor packaging during transport were the main reasons for post-harvest losses. Five to fifty percent post-harvest losses are due to physical, physiological and pathological damage. Tomatoes must be harvested at the right time as overripe tomatoes are more susceptible to physical injury than ripe and pink ones. They must be packed properly to avoid injury that would cause softening and decay and protected from bruises and blemishes (they are put in wooden or plastic crates or bamboo baskets after being harvested).

3.3.2 Post-harvest Losses in Fruits

About 25-45 percent of the harvest of many tropical fruits is wasted due to improper handling, diseases and lack of facilities to extend the storage life. The most important post-harvest disease and disorders in Sri Lanka are anthracnose, stem end rot, water blister and internal browning of pineapple, Penicillium decay of citrus, Phytopthera rot in durian and transit rots caused by Rhizopus spp. and Geotrchum spp. (Adikaram, n.d.).

Soft nature of fruits and vegetables, high water content and high rate of respiration contribute to losses. Bruising is the major factor causing rotting (physiological and fungal) although insects, rodents, birds also amplify losses.

Latent infection, mainly anthracnose and stem end rot on fruits caused by Collectotricum spp. and Botryodiplodis spp. is probably the most important cause of post-harvest losses of tropical fruits. The fungi are known to attack a wide range of fruits including banana, mango and papaya. Fungi infect fruits at any time during the fruit ripening process. The pathogens manifest themselves during the fruit ripening process.

3.3.2.1 Pineapple

Pineapple *Ananas comosus* (L.) is an important fruit crop grown in Sri Lanka both for the local market and for export. The main cultivar grown in Sri Lanka is Mauritius. Mauritius pineapples are grown for consumption in the fresh form and are harvested immediately prior to colour development. Higher acidity and lower sugar levels in fruit prior to colour development, as compared to those harvested at 25 percent of shell colour development, result in low quality of the ripened product.

Fresh pineapple is mainly exported under refrigerated conditions by air freight. The storage potential of fruits is crucial for the long term shipment (Sarananda, 2008).

Internal Browning

Internal browning (IB) which is also known as indigenous brown spot or black heart development is a major problem in the export of fresh pineapple under refrigerated conditions. This is a physiological disorder which cannot be identified externally. It affects the quality of fruits and reduces the market value due to off flavour and off colour. The cause of high post-harvest losses during sea shipment was identified and established as being due to the temperature related physiological disorder referred to as endogenous brown spot, black heart of pineapples, internal browning. It was observed that cayenne type Kew variety shows less susceptibility to the disorder compared to the popular queen type Mauritius variety (Selvarajah et al., 1999).

Pineapples are loaded in trucks without any packaging. Compression damage due to over loading is a major cause of loss. In addition, the slanted cut end of the stock penetrates other fruits causing high levels of mechanical damage and resulting in very high losses.

Post-harvest handling systems contributed to quality deterioration to a certain extent and poor handling techniques from field to retail outlets cause 18 percent of loss.

3.3.2.2 Mango

At present the post-harvest losses of mangoes in Sri Lanka are estimated to be in the range of 40 to 60 percent of the total harvest. The post-harvest physiology of mango fruit is characterized by a rapid rate of ripening and senescence. Control of these processes is essential for extending the storage life.

Main post-harvest diseases related to mango are anthracnose and stem end rot leading to high post-harvest losses (20-30% post-harvest loss). Fungal infection is the principal cause for post-harvest decay of mango during ripening (Jayasooriya, 2002). In mango, susceptibility to post-harvest diseases depends on the variety and the storage condition. The Velaicolomban variety was susceptible to Colletotricum and stem end rot diseases. Harvesting mangoes at the fully matured stage and bagging minimize disease incidence and physical damage while enhancing appearance.

Karthakolomban – Fungal rot at the stem end and patches on the skin due to Anthracnose are the two major fungal diseases that cause severe post-harvest losses in Karthakolomban. Infection takes place when fruits are attached to trees and symptoms develop when fruits ripe. Mangoes harvested at fully matured stage, fruit undergo normal ripening resulting in delicious ripe fruit with minimum disease incidence. Immature fruits take relatively longer time for natural ripening than fully matured fruits. During this long period of ripening, development of disease symptoms can be observed (Jayathilake et al., 2009).

It is a common practice that mango traders visit mango producing areas and harvest all the mangoes in the tree in one picking. Bulk transport is very common to transport mangoes from field to collection centres. Only karthakolomban variety is packed in tea chests or wooden crates when transported from field to the collection centres. Bruising damage, latex stains and compression damage affect external appearance thereby lowering the consumer attraction. Immature mangoes do not ripe naturally; even if ripen the quality tends to be poor. Immature harvesting leads to poor quality fruits as well increased susceptibility of fruits to disease. At retail level mangoes are sorted daily and rotten mangoes are disposed. A large portion of mangoes are sorted and disposed mainly due to pathogenic rot. Stem end rot caused by *Botrioduplodia theobromea* and anthracnose caused by *Colletotricum gleosporiodes* are the two major fungi causing this (Snowdon, 1980; cited in Sarananda and Amarakoon, 1999).

3.3.2.3 Banana

Banana is the most important fruit crop in Sri Lanka in terms of the cultivation extent, production and consumption. Banana is a climacteric fruit and perishable in nature having relatively high post-harvest losses of about 20-30 percent (Ekanayake and Bandara, 2002; Sarananda, 2000). This is mainly due to physical damages caused during handling and transportation with the delicate nature of the fruit when it ripes and lack of suitable infrastructure for transport from production point to consumers. Short storage life and crown-rot caused by several fungi are the major problems associated with the export of this commodity. Internal browning that affects fruit quality (brown coloured flecks can be observed all over the flesh concentrated more towards the nipple end. These flecks extend up to the outer tissues of the flesh but not to the peel) is a problem in banana that has been observed for a long time affecting the fruit quality severely. This disorder is commonly found in the low country wet zone. The banana varieties ‘Kolikuttu’ and ‘Ambul’ are mostly affected. Moisture stress and nutrient deficiencies were suspected to be the causal factors.

Although banana is harvested at the mature green stage, the external appearance of the ripe banana displayed at the retail shops may be poor due to excessive bruising, abrasion and diseases resulting from improper handling throughout the supply chain (Sarananada, 2000). However, the loss is due to multiple factors while poor packaging being the leading cause.

Bananas are usually packed in trucks without using proper packaging or any cushioning or lining materials in the traditional distribution channels, which accounts for about 97 percent of the local marketing (Dharmasena and Sarananda, 2012). When transporting, banana bunches are stacked horizontally by keeping bunches one over the other into number of layers. The wholesaler generally attempts to transport maximum amount of produce per truck load to minimize transport cost. The loss is further aggravated due to slipshod handling during unloading at the turning points and the final destinations. Furthermore, fewer transport trucks are exposed to the direct sun and rain which prompt deterioration of the fruit quality. The mechanical damage not only leads to post-harvest losses but also create various physiological stresses to fruits leading to physiological and morphological changes while being identified as a major cause of post-harvest loss even in international marketing channels.

Wasala et al., (2014) in a study of post-harvest losses, current issues and demand for post-harvest technologies for loss management in the main banana supply chains in Sri Lanka, estimated a total of 28.5 percent post-harvest loss (as Farmer-1%, Retailer-10%, Transport-8.5%, Wholesalers'/Bulk transporters-9%). The study found that a vast majority of the stakeholders preferred and were practicing transporting bananas in bunches bulk packed in vehicles. All the farmers preferred to sell bananas in the whole bunch as it is easy to transport, easy to sell, the buyer can easily inspect the whole bunch, less handling and the market demand. They preferred to use fresh leaves over dry leaves since it reduces damages caused to the bunch and dry leaf might cause abrasion damages on fruits' surface. The study recommended the need for suitable bulk packaging method for transporting the whole bunches and continuous training and awareness programmes should be conducted.

3.3.2.4 Papaya

Marketing of fresh papaya has becoming a great problem due to short shelf life leading to high post-harvest losses. High level of mechanical damage, disease development, presence of 'green islands' on the skin and poor quality of the flesh, contribute to quality loss. Post-harvest loss of papaya is reported to be 46 percent (Sarananda, 2000). Mechanical damages caused during harvesting and transport and post-harvest diseases are the major causes for post-harvest losses. The internal firmness of papaya variety 'Rathna' is an advantage, which leads to less post-harvest loss due to mechanical damage. However, slightly lesser taste of fruits, very high incidence of green islands on the skin has reduced the consumer demand for this variety. In addition, relatively higher disease incidence in ripe fruits increases the post-harvest losses. Of the mechanical injuries, abrasion and puncture injuries have been reported as causes for the 'green island' formation. Abrasion damage of papaya is associated mainly with fruits being brushed against the inner sides of the storage basket. If proper packaging is not used, the possibility of abrasion damage is greater and in turn, the quality of papaya at retail market will decline (Sarananda et al., 2004).

3.3.3 Post-harvest Losses in Leafy Vegetables

Wilting due to water loss, senescence-associated discolouration (yellowing or browning), mechanical injury, high respiration rate and decay or rotting are the main causes of quality deterioration and post-harvest loss of leafy vegetables. These causes of quality loss are physiological, pathological and mechanical in nature.

Physiological deterioration - Leafy vegetables mostly contain water (>90%) and have the propensity to lose water through transpiration. Water loss is the main cause of weight loss (loss in saleable weight) and wilting. A loss of five to ten percent of fresh weight would make leafy vegetables appear wilted and become unusable. Water loss also induces degradation of nutritional components (e.g. vitamin C loss) and imposes stress (i.e. water stress) that increases respiration and ethylene production (Kanlayanarat, 2007).

3.4 Reduction of Post-harvest Losses

Horticultural products are easily bruised, rendering the product unsaleable due to their soft texture. Breaking the skin or bruising the flesh release proteolytic enzymes, hastening decomposition and opening the way for bacteria and fungi that cause rotting. Therefore, all horticultural products should be handled gently to reduce losses due to bruising and rotting. Bruising is probably the major cause of losses in Sri Lanka.

Reduction of post-harvest losses can lead to offer of a more reasonable price to the farmer as well for the consumer. Post-harvest losses include both quality and quantity loss. The poor quality of fruits and vegetables available in the market is a serious problem for consumers. In addition, often the nutritive value of fruits and vegetables is highly affected when they reach the consumers. Post-harvest loss of a commodity cannot be reduced by adopting improved post-harvest technologies alone, because the effect of the pre-harvest factors such as crop management and field sanitation also contributes to crop losses. Well managed orchards or vegetable fields produce high quality fruits and vegetables which have a potential for longer post-harvest life. In order to reduce post-harvest losses producers and handlers must understand the biological and environmental factors involved in identifying causal factors and they need to use pre-harvest and post-harvest techniques to maintain the best possible quality. Lack of plant foods in the soil can seriously affect the quality of the fresh produce at harvest. Nitrogen and potassium play an important role in the storage quality of vegetables.

Pre-harvest fungicide treatment, sanitation, bagging and other field management practices and careful post-harvest handling can reduce a majority of post-harvest disease problems as many such diseases begin in the field. A combination of sanitation, bagging and monthly application of fungicide reduced freckle disease, anthracnose and crown rot of banana significantly. Chemical usage should be rational and restricted mainly to the pre-harvest phase and only the non-residual, safe and internationally accepted chemicals should be used for post-harvest

treatments. Physical methods such as hot water, aerated hot steam treatment and waxing should be popularized (Adikaram, n.a.).

3.4.1 Fruit Bagging and Covering

Fruit bagging is a useful practice in preventing field infections with many fruit crops. Paper or polythene bags could be used for this purpose. Bagging creates a dry micro environment in which fruits can develop with comparative freedom air and water borne inoculum, free water to facilitate infection and damage by piercing insects (although scale insects and mealy bugs can proliferate). Bagging has been shown to be effective in reducing freckle disease in banana, stem-end rot and anthracnose in mango (Adikaram, n.a.).

3.4.2 Natural Substances as Fungicides

A number of natural products with potential fungicidal properties are emerging as useful chemicals. Chitosan, produced by the deacetylation of chitin has proven effective in suppressing post-harvest pathogen development. Chitosan has the ability to form films that can be used to coat the surface of fruit and regulate gas and moisture exchange. When applied as a coating, chitosan reduced ripening, incidence of decay and in certain instances stimulated defense responses in tissues. Reduction of decay with chitosan has been reported for tomato, cucumber and pepper varieties.

Papaya latex has excellent properties to be used as a post-harvest fungicide. Diluted papaya latex can completely digest the conidia of a number of important post-harvest pathogens. The ability of an unripe papaya fruits to resist fungal rotting is directly related to the presence of latex and its fungicidal property. Application of diluted latex onto the freshly exposed crown tissue of banana prevented the development of crown rot and delayed fruit ripening. Further, dipping wood apples in diluted latex reduced post-harvest fungal development. Latex may cause damage to fruits with delicate skins (Adikaram, n.a.).

3.4.3 Timing of Harvest

Fruits must be harvested at correct maturity stage to obtain a higher quality ripe fruit. Fruits can be divided into two major groups based on their post-harvest behaviour.

Table 3.5: Major Fruit Groups according to Post-harvest Behaviour

Climacteric	Non-climacteric
Increased respiration during ripening	Continuous decline in respiration
Peak ethylene production during ripening	Very low ethylene production
Ethylene production can be triggered	Ethylene production cannot be triggered
After harvesting ripening changes take place	No ripening changes after harvesting
Banana, mango, papaya, avocado, jak fruit, sour sop	Citrus, rambutan, mangosteen, pineapple, grapes

Harvesting is one of the most important activities in the post-harvest life of fruits. Harvesting of non-climacteric fruits at ripe stage is very important because these fruits do not proceed towards ripening changes after harvesting.

Fruits should be harvested using maturity indices developed for each fruit to get the maximum quality. Fruits must be harvested in the morning of a sunny day when dew disappears (Sarananda, 2000).

Use of proper harvesting equipment also reduces mechanical damage. Harvesting equipment developed by institutions in Sri Lanka has been introduced to growers. By using picking poles damage to the fruit can be prevented. Fruits must be harvested into a rigid container and fruits must never be allowed to touch the soil. Contact with the soil can cause minor injuries and these injuries serve as entry points for microorganisms. Fruits are best harvested in early morning; between the sunrise and 8.00 a.m. Fruits harvested at mid-day or mid-afternoon have poor keeping quality, owing to their high respiration rates. Mangoes should be harvested between 10.00 a.m. and 3.00 p.m. to minimize latex burn on the fruit. Washing after harvesting is important for the removal of field heat. Use of proper sorting and grading systems increases the shelf life of produce, as well as grower income.

3.4.3.1 Leafy Greens

Leafy greens should not be harvested during the heat of the day. Harvest operations should be completed by 8.00 a.m. Products must be stacked in the shade and transported to the pack house for preliminary cooling without delay.

3.4.3.2 Vegetables

Vegetables must be harvested at the correct stage of maturity and with extreme care in order to ensure maximum shelf life and keeping quality. Harvest operations should commence early in the morning to minimize exposure to direct sunlight and reduce heat buildup within the product. Harvested produce should not be heaped on

the ground, but carefully laid out in the shade prior to packing. Diseased and damaged produce should be removed during sorting and grading operations.

Vegetables such as okra, mae, beans, drumstick and luffa should be harvested at the tender stage. If these vegetables are harvested at the mature stage, rapid toughening takes place due to formation of fibre. Vegetables such as carrot, radish, knolkhol, beetroot and cabbage should be harvested at their specific maturity stages. Early harvesting of these crops results in poor yield while delayed harvesting causes very high loss due to cracking of roots or stem. Green chilli should be harvested at mature green stage while cucumber should be harvested when immature and before the skin turns brown.

Okra – Harvesting of pods eight to nine days after flowering is the best stage of maturity which gives high yield with a long post-harvest period of seven days (Ranasinghe, 1997).

3.4.3.3 Fruits

Fruits should be harvested at the optimum stage of maturity.

Pineapple

Pineapple needs to be harvested at the 10-20 percent yellow stage of ripeness (when one to two rows of "eyes" at the base of the fruits are turning from dark green to yellow) for optimum flavour development. Fruits are best harvested in the dawn to 8.00 a.m. Fruits harvested at mid-day or mid-afternoon have poor keeping quality. Stalks must be between six to eight inches long at harvest. Rough handling must be avoided at all stages when harvesting, trimming, cleaning or packing operations.

Harvested fruits must not be allowed to lie around in the sun. Pineapples should be transferred and collected in a shady spot. Fruits must be carefully brushed to remove insects such as ants and mealy bugs. Stems must be trimmed to a length of 1" to 1.5". Knives use for harvesting and stalk trimming operations should be disinfected at regular intervals by dipping the knife blade in a 20 percent solution of bleaching powder.

When exporting pineapple fruit, they are packed in adequately ventilated compartmentalized, five ply corrugated fibre board cartons. Ventilation apertures must not be covered by sealing tape during packing. Optimum low temperature storage conditions recommended for pineapples include a holding temperature of $10^{o}C$ with relative humidity maintained at 85-90 percent.

Rambutan should be harvested when colour development has reached full blush. Jak fruit, *polos* (baby jak) and bread fruit need to be harvested at the dull green/olive green stage of maturity. Bananas should be harvested at mature green stage.

Bananas for air shipment may be harvested at a slightly later stage of maturity than those intended for sea shipment.

Papaya

Papaya is usually harvested at immature stages of development, owing to difficulty in identifying the exact stages of maturity required for minimal injury during transport. Immature fruits do not ripe naturally and if they do, are of extremely poor quality. When transported to distant areas, the harvesting at 10 percent yellow stage is better and for transporting to nearby shops, harvesting at 20-25 percent yellow colour is suitable. For Red Lady and Ratna varieties, harvesting should be done at 30 percent yellow colour stage. If manual harvesting is difficult improved harvesting tools should be used (Sarananda and Wijesooriya, 2008).

Mango

Mango is usually harvested at immature stages of development, owing to difficulty in identifying the exact stages of maturity required for minimal injury during transport. Immature fruits do not ripe naturally and if they do, are of extremely poor quality. Mango harvested at an immature stage exudes latex which results in skin burns and high post-harvest losses.

Harvesting at optimum stage of maturity and harvesting mango with a long fruit stalk can minimize latex exudation resulting in lesser latex burn. Best time to harvest mango is between 10 a.m. to 3 p.m. when latex exudation is low. Post-harvest rotting caused by anthracnose and stem end rot can therefore be reduced by careful harvesting of mature fruits and using rigid containers to transport them (Sarananda and Amarakoon, 1999).

In most part of the country, in terms of mango traditional manual harvesting method is still practised, which consumes more time and labour. The structure of the mango tree and irregular maturity period are the major obstacles for introducing mechanical harvesters. Cutting edges, holding pouch, nylon chute, galvanized pipe and cable operating mechanism are the main components in the improved mango harvester. When pulling the cable outward holing pouches are opened, once it is released pouches are closed. Cable was extended up to the bottom of the galvanized pipe. Harvested mangoes were directed towards the ground through nylon chute (Risvy and Thanaraj, 2011).

The harvested crop should be taken to a shady place, sorted, graded and packed at a ‘Packaging Centre’. The packaging material should be strong enough to support the produce, but should be sufficiently ventilated. Polypropylene sacks are not recommended to use in packaging. Compression damage due to over packaging and vibration damage during transportation are the cause of serious losses. The “Fresh Produce Concept” introduced by the Institute of Post-harvest Technology is mainly focused on introducing maturity indices, time of harvest, sorting and grading of produce followed by suitable packaging material to reduce handling and transport

losses in fruits and vegetables. The introduction of returnable and nestable plastic crates in post-harvest handling will reduce post-harvest losses in fruit and vegetables, particularly during transportation.

3.4.4 Proper Packaging

A major cause for post-harvest loss of fruits and vegetables is due to use of improper packaging during transportation (Jayathunge et al., 2011). Considerable losses during transportation occur because of unsatisfactory packaging, lack of ventilation in the lorries, poor facilities for handling produce in the Colombo wholesale market and the extreme traffic congestion and inordinate delays before unloading. The most common form of packaging is in jute or gunny and polysack bags in which fruits are packed tightly and then stacked in lorries up to roof height, denying ventilation. Self-heating and accumulation of respiratory gases and moisture cause major losses which are then aggravated by the hot humid conditions and direct sunlight characteristic of most retail vegetable stalls in the city.

Some lorries lack proper covers (hood) to protect (especially from sunburn, rain) vegetables and fruits during transport. Hence, lack of proper transportation mechanism and method of transportation apparently leads to low quality of goods received to Manning market and consequently to final consumer and high wastage. It was clearly noted that method of transportation and packing are the main factors affecting quality of harvest, especially for most perishable goods.

Fresh produce should be packed in rigid, ventilated, shallow containers. For this purpose, plastic crates can be used. These crates protect the produce from mechanical damage and temperature build up. However, most of the vegetables are transported in polysac bags is the major reason for excessive post-harvest losses in the country. For fruits such as tomatoes, papaya and guava, wooden crates are used.

In order to prevent serious post-harvest losses of fruits and vegetables, the Institute of Post-Harvest Technology (IPHT) launched a development project to introduce plastic crates to fruit and vegetable supply chains at 50 percent and 75 percent subsidized prices. Furthermore, government imposed a rule that fruits and vegetables should be transported in safe packages to minimize post-harvest losses and to supply quality produce to the consumer. By a special Gazette issued on October 2011, enforcement of ‘Crate Law’ prohibited the use of gunnies for transporting vegetables and fruits Island wide. This law was enforced to reduce the spoilage of vegetables and fruits during transport. But in the wake of a wave of protests by farmers, wholesalers and transporters the government retracted making the rule stand only for 11 vegetables and 8 fruits varieties (Wasala et al., 2012).

Package must be easy to handle, easily stackable, not excessively heavy and of appropriate dimensions and shape to fit the transporting vehicle.

Packaging Materials

1. Natural material – such as woven baskets of bamboo, willow or straw have the advantage of being cheap, readily available and familiar to the users. Disadvantages are;

- Impossible to clean and sterilize
- Lack of rigidity which prevents multiple stacking
- Often filled too tightly causing pressure bruising
- Being too large to handle easily
- Have many sharp edges which pierce and wound the produce

2. Wood - wooden boxes are widely used in many countries and can be manufactured from sawn wood for reusable crates. Wooden boxes have the advantages of being rigid, re-usable and often available locally. Their disadvantages are;

- Difficult to clean and sterilize
- Heavy to carry and transport
- Often have rough surfaces, sharp edges and protruding nails

3. Corrugated cardboard or fibre board – boxes or cartons have the advantages of being portable, clean, smooth surface, attractive and allow application of labels and can be manufactured with different sizes, shapes and strength. Disadvantage are;

- Not re-usable
- Easily damaged by water and rough handling

4. Plastic containers – can be manufactured to a wide variety of specifications and colours. They have the advantage of being strong, easy to handle and clean, smooth surfaced, rigid and returnable.
   Disadvantages are;

- Expensive
- Difficult to organize return journeys over long distances
- Unsuitable for export

5. Bagging or nets – come in a variety of sizes, shapes and strength and can be manufactured from natural or synthetic fibre. They have the advantage if being light, often re-usable, can be manufactured locally and often very cheap. Disadvantages are;

- Except potatoes and onions, they do not protect the produce sufficiently and cannot stack when containing tender produce
- Are often too large for convenient handling and tend to be thrown rather than placed
- Mesh sizes are often too fine to allow for sufficient ventilation of produce

6. Paper or plastic film – are frequently used as liners or dividers inside packing boxes to reduce water loss, prevent friction damage or provide extra support. Disadvantages are;

- Increase the cost of the package

Jayathunge et al., (2011) studied the effects of different types of packages of vegetable crops during handling and transport. The economic feasibility of each package type for handling and transportation of each commodity was calculated using cost-benefit analysis. Losses using the traditional packages (sacks) ranged from 10 to 30 percent for a variety of vegetable crops, while losses when using improved packages were generally reduced to five percent or less. For green beans, post-harvest losses when handled in sacks was measured to average 22 percent, while the same crop handled during the same time over the same route suffered only 4.6 percent losses when handled and transported in nestable plastic crates. According to Jayathunge et al., (2011) rigid packages used for the study selected from those available in the market and also those developed by various institutions were used for evaluation are listed below. Different types of rigid containers suitable to pack vegetables were identified.

1. Nestable plastic crate (large) – available in local market
2. Nestable plastic crate (small) – available in local market
3. Collapsible plastic crate (large)
4. Collapsible plastic crate (small)
5. Collapsible steel crate - designed by NERD centre
6. Wooden box (type 1) - designed by ITI
7. Wooden box (type 2) - designed by IPHT
8. Wooden box (type 3) - designed by IPHT
9. Fibreboard box – available in local market
10. Wax coated fibreboard box - available in local market

Smaller nestable plastic crate (52.5x35x30 cm) was identified as the most suitable package for handling and transportation of tomatoes and the large nestable plastic crate (60x42.5x30 cm) was identified as the most suitable package for other vegetables such as beans, cabbage, brinjals (eggplants) and green chilies.

According to Ilangakoon et al., (2015) use of safe packaging (crates) was limited due to many constraints. Most common were the unavailability of plastic crates for purchase, packing in plastic crates is expensive than using gunnies, high cost of transportation since crates occupy more space than when packed in gunnies and therefore more vehicles are needed to dispatch the whole load, no assured mechanism of returning safe packages moving through the supply chain and traders do not have adequate facilities to receive vegetables in crates (e.g. enough storage facilities).

Dissanayake (2015) conducted a study to assess the present status of the use of safe packages for fruit and vegetable transportation, to identify stages and types of safe packages used and the benefits and constraints of using safe packages in transporting perishables. The study revealed that all beneficiaries were aware of the benefits such as prevention of losses and quality retention in using safe packages in perishable transportation. Unlike for vegetables, safe packages are used for packing and transporting fruits such as mango, papaya and guava. Mostly used safe packages were plastic crates, corrugated fiberboard boxes and wooden boxes.

3.4.5 Transportation of Fruits and Vegetables

Of the total post-harvest loss occurring in fresh produce, the loss during handling and transportation alone amounts to approximately 20 percent (Jayathunga et al., 2011). Fresh produce is primarily transported by road, from farmer to consumer. A marketing concern is that the prime condition of fresh produce should be preserved during transportation. Minimizing losses during transportation, necessitates that special attention be given to vehicles, equipment, infrastructure and handling. Fresh produce is transported using both refrigerated and non-refrigerated vehicles.

Non-refrigerated vehicles are generally open-sided trucks, with wire mesh frames. This type of transportation is inexpensive, convenient and easy. Trucks can be used for the delivery of fresh produce, other goods and passengers when required. Layers of produce are not, however, separated to prevent heat generation. Often the produce is stacked too high.

Non-refrigerated vehicles are used for transporting produce over distances of up to 850 km. On arrival the produce must be unloaded or sold as quickly as possible to overcome overheating. Fresh produce must not be watered prior to loading as this will lead to decay, rotting and extensive losses.

Major causes of losses during the non-refrigerated transportation of fresh produce;

- Improper handling during loading and unloading
- Overloading without separation of produce which leads to overheating and mechanical injury to produce at the bottom of the stack
- Rough roads
- Lack of ventilation of the produce

Most supermarkets use refrigerated trucks and plastic crates for packing and transporting of fruits and vegetables and with that system they were able to reduce wastage to around five percent. This improved transport system adopted by the supermarkets is estimated to be above 50 percent more expensive than the conventional system, but the cost disadvantage is well compensated by the improved product quality and higher overall prices (Vidanapathirana, 2008). Certain leading supermarkets have established teams of officers to provide advice to farmers on how to minimize post-harvest losses and to improve quality. Some of the major supermarkets have substantially reduced their losses by engaging in processing and value addition.

Reefer vans are becoming very popular for transportation of high value fruits and vegetables, especially to metropolitan cities. In these vans there is precise control on temperature and relative humidity to keep fruits and vegetables fresh for a long time. Major supermarkets in Sri Lanka use reefer trucks to transport vegetables from collecting centres to Colombo (Vidanapathirana, 2008).

3.4.6 Storage of Fruits and Vegetables

Generally, a common storage facility lacks for fruits and vegetables. The usual practice of farmers is to harvest the product (especially fruits and vegetables), when there is way to transport the harvest directly to the market. Normally, there are small and large scale vegetable and fruit collectors in farming areas, who collect the harvest from the farmers. Due to the absence of storage facilities with farmers, large volumes of vegetables and fruits from one area frequently arrive in the market on the same day. If the demand for the product is less, or the product is over-supplied, prices on that particular day are drastically reduced.

Commission agents and wholesalers in special economic centres at Dambulla or at Manning market have no space to store surplus supply for a reasonable time. In the case of excess supplies to the market, there is no post-harvest food processing centres close to economic centres or wholesale markets. Hence, vegetable and fruit prices are volatile than other food commodities in Sri Lanka and it directly influences low income buyers, farmers, and members of supply chain.

3.4.7 Processing of Fruits and Vegetables

Processing activities expand the market opportunities for fresh fruits and vegetables, add value and bring about vertical diversification within the fruit and vegetable sector while minimizing post-harvest losses. Traditional processing technologies such as canning, bottling, freezing and drying are widely applied at various levels and scales of technologies. Application of mild processing, packaging technologies and natural preservation systems in the preservation of fruits and vegetables is on the rise.

3.4.8 Current Best Practices to Minimize Post-harvest Losses of Fruits and Vegetables in Sri Lanka

Most supermarkets and exporters use refrigerated trucks/reefer trucks and plastic crates for packing and transportation of fruit and vegetable and with that system they were able to reduce wastage to around five percent. Some leading supermarkets have established teams of officers to provide advice to farmers on how to minimize post-harvest losses and to improve quality. Some of the major supermarkets have substantially reduced their losses by engaging in processing and value addition.

Supermarkets are more selective in their purchasing and farmers have to supply better quality fruits and vegetables where farmers receive high price compared to other conventional channels. They have collecting centres established in major producing areas for direct procurement of vegetables from farmers. Farmers used to supply good quality harvest for these collecting centres and vegetables are further sorted according to the visual quality characteristics. The good quality vegetables are packed in plastic crates and transported to the distribution centres in Colombo in reefer trucks. At the distribution centres workers sort out the bulk vegetables, clean

them and package them. From the distribution centre, vegetables are dispatched to individual outlets in Colombo and suburbs either in freezer trucks or non-freezer trucks (Vidanapathirana, 2008).

When exporting vegetables and fruits, leading exporters have their own transport agents supplying the produce at the exporter's store at the correct time (at least 10-12 hours before the flight). Transport agents are aware of the exporter's buying price, before collecting. At the exporter's store, the produce is sorted and graded according to overseas buyer's requirements. Quality produce is packed for export and the transport agent is paid the agreed price.

A new system with the backing of the Sri Lanka Export Development Board has come into effect. It is the model of establishing collecting centres by exporters at major agricultural locations. This new model, which has been already tested with success, encourages good post-harvest practices complimented by good marketing arrangements where the farmers are assured of a higher price than the village *pola*/wholesale market price, for quality produce. This marketing arrangement also encourages farmers to collectively market their produce at the collecting centre while ensuring the exporter of purchasing the total export volume from the collecting centre. Collective marketing will enable farmers to sell the export rejects (fit for human consumption) at the local market and economize on cost of transport to the collecting centre. Collective farming will enable farmers to economize on cost of farming practices (Dias, 1994).

When exporting fruits and vegetables, the consignment should arrive in the airport six hours and at the seaport 24 hours prior to the shipping for cooling. During this period the quarantine requirements and the customs procedures are undertaken. Phytosanitary Certificate issued by the Plant Quarantine Service of the Department of Agriculture is required by the importing country, when exporting perishable items such as fruits and vegetables.

For exporting, the quality is checked mainly by appearance, correct maturity, size and weight in addition to relying on certification (HACCP, GMP, GAP, ISO 22000), based on buyers' requirements. Most exporters send their products to either Asia (mainly Maldives), the Middle East or to both. These markets do not require stringent quality standards and quality certification. To export to Europe and to the USA high quality certification such as Global GAP is required.

3.4.9 Future Challenges in the Fruit and Vegetable Post-harvest Sector

- Reduction of present post-harvest losses
- Improvement of post-harvest handling systems
- Introduction of quality management
- Improvement of safety standards
- Promotion of export through better post-harvest management
- Management of surplus production
- Changing consumption to frozen or preserved forms

- Promotion of functional foods for improved health
- Production and post-harvest management under climate change

Source: Dharmasena and Sarananda, 2012

3.5 Research based Evidence to Minimize Post-harvest Losses of Fruits and Vegetables in Sri Lanka

Pre-harvest fungicide treatment, sanitation, bagging and other field management practices and careful post-harvest handling can reduce a majority of post-harvest disease problems, as many such diseases originate in the field. A combination of sanitation, bagging and monthly application of fungicide reduced freckle disease, anthracnose and crown rot of banana significantly. Chemical usage should be rational and restricted mainly to the pre-harvest phase and only the non-residual, safe and internationally accepted chemicals should be used for post-harvest treatments. Physical methods such as hot water, aerated hot steam treatment and waxing should be popularized.

Table 3.6: Research Conducted to Minimize Post-harvest Losses in Fruits and Vegetables in Sri Lanka

Post-harvest Issue	Research	Measures
	Papaya	
Short shelf life leading to high post-harvest losses.	Effect of Oxalic Acid, Ethanol Vapor and Packaging on Post-harvest Performances of *Carica papaya* (Variety Red Lady), (Madakumbura et al., 2008)	Shelf life of papaya could be increased by using 9ppm oxalic acid coupled with CFB boxes + LDPE lining + scavengers as the better performing packing techniques retain most of the physiological and biochemical characteristics of fruits.
	Development of Composite Wax Formulation for Shelf Life Extension of Papaya (Wijewardane and Thilakarathne, 2012)	Wax formula (palm oil 0.8%, glycerol 12%, tween 0.8%, guar gum 1.2%) mix with water 1:2 ration extend the shelf life of papaya upto 9 days at 29-32^{0}C and 65-70% RH.
	Prolong the Post-Harvest Life of Papaya Using Modified Atmosphere Packaging and Waxing (Prasad, 2005)	Hot water dipping at 50^{o}C for 20 minutes after spraying 5% ethanol followed by packaging in 0.075 mm LDPE was successful in extending the post-harvest life of papaya over 12 days under ambient condition (31 $^{+}_{-}$ 2 ^{o} C and 65 $^{+}_{-}$ 5 RH). Papaya fruits being dipped in hot water at 50^{o}C for 20 minutes after spraying 5% ethanol followed by application of 6% of Paraffin wax-emulsion maintain the good visual appearance and recorded the lowest weight loss during 15 days of storage under ambient condition (31$^{+}_{-}$ 2^{o}C and 65$^{+}_{-}$ 5 RH).

Table 3.6 (contd.): Research Conducted to Minimize Post-harvest Losses in Fruits and Vegetables in Sri Lanka

Post-harvest Issue	Research	Measures
Post-harvest loss during storage and transportation due to Anthracnose disease	Effect of Chitosan Coating on Post-harvest Life of Papaya Variety Rathna Grown in Sri Lanka (Hewajulige et al., 2006)	Chitosan treatment 1% extracted from locally available prawn waste improved the keeping quality reaching 70-80% marketability after 14 days at 13.5^0C and 95% RH (cold storage)
Mechanical damages and formation of green island	Quality of Papaya Variety 'Ratna' as Affected by Post-harvest Handling (Sarananda et al., 2004) Effect of Harvesting Maturity, Packing Material and Hot Water Treatment on "Green Island" Formation of Rathna Variety of Papaya (Marasinghe, 2001)	Wrapping individual fruits in Styrofoam net or newspaper prevents mechanical damage during transport. By applying this method bruising the fruits can be minimized as the wrappers provide a padding effect. Both maturity stage at harvest and packaging materials used during transport will lower the formation of 'green island'. Minimum weight loss was recorded in papaya fruits harvested at 50% yellow colour stage.
Banana		
Post-harvest Issue	**Research**	**Measures**
Internal browning that affects fruit quality	Impact of Boron and Calcium on Internal Browning of Banana (Wanniarachchi et al., 2009)	Foliar application of boron as 0.5% Borax or calcium as 0.5% calcium nitrate at 3, 5, 7 months after planting reduced the Internal Browning up to 80%.
Improper post-harvest handling practices	Development of a Transportation Package for Banana (Wasala et al., 2014) Vibration Simulation Testing of Banana Bulk Transport Packaging Systems (Wasala et al., 2015)	Use of Styrofoam sheets of 8mm as layers is the suitable method to transport banana. Mechanical damage can be reduced from 26.3% to 12.9% using 8mm thick Styrofoam sheets as a cushioning material between banana bunch layers.

Table 3.6 (contd.): Research Conducted to Minimize Post-harvest Losses in Fruits and Vegetables in Sri Lanka

Post-harvest Issue	Research	Measures
Crown rot and weight loss of ambul variety during storage	Controlled Atmosphere Storage of Ambul Bananas (Sarananda and Wijeratnam, 1994)	Storage life of *'Embul'* bananas can be extended up to 30 days by storing them in 1-5% oxygen at 13.5°C. No external and internal qualities of ripe fruits were affected by these forms of low oxygen treatment.
Crown rot in Banana due to fungal infection.	Post-harvest Technology of Fruits (Sarananda and Wijesooriya, 2008)	This disease occurs on the surface of cut bunches. Application of Bavistin fungicide 1g in 1l of water can control the disease.
Short shelf life leading for high post-harvest losses.	Extension of Post-Harvest Life of Fresh Banana Bunches using Modified Atmosphere Package under Ambient Condition. (Ranasingha, 2006)	Dipping in hot water (50^0C) for 20 minutes after spraying of 5% ethanol followed by packaging 0.0375mm LDPE was successful in extending the post-harvest life of banana over 8 days under ambient condition (30+-2^0C and 62+-3% RH).
Mango		
Post-harvest Issue	**Research**	**Measures**
Anthracnose and Stem-end rot	Effect of Bagging on Post-harvest Quality of Mango Variety "Karuthacolomban" (Jayathilake et al., 2009)	Bagging of fruits is effective in controlling diseases and insects and enhances appearance. Bagged fruits reached early maturity and took less time to ripe.
	Qualitative Post-harvest Losses in Mango (Thantirige et al., 1993)	Fruits treated with 1000 ppm Benomyl (50% w/w) at 52-55^0C for 5 minutes and subsequently packed in 150 gauge sealed polythene bags maintained quality up to a period of 11-14 days.
	Methods to Minimize Post-harvest Rot of Local Cultivars of Mango (Sarananda and Amarakoon, 1999)	Careful harvesting of mature fruits and using rigid containers to transport them. Mangoes should not be washed after harvesting. Harvesting fruits at 12 weeks after flowering. Hot water treatment (dip mangoes for 3-5 minutes at 52^0C).

Table 3.6 (contd.): Research Conducted to Minimize Post-harvest Losses in Fruits and Vegetables in Sri Lanka

Post-harvest Issue	Research	Measures
To extend the storage life of mango varieties in Sri Lanka	Post-harvest Changes in Three Varieties of Mango (*Mangifera indica*) as Affected by Pre and Post-harvest Treatments (Krishnapillai et al., 1996)	Spraying of 10,000 pm $CaCl_2$ with Teepol at pre-harvest stage extended storage life by four days. Cold stored fruits with $KMnO_4$ was the best treatment for mango considering the storage life and acceptability.
Poor colour development of peel and stem end rot in Karthakolomban	Effect of Hot Ethral Dip Treatment for Improving Peel Colour Development and Reducing stem end Rot of Karthacolomban Mango (Sarananda et al., 2004)	Treating harvested, matured mangoes with hot ethral at 52^0C for 3 minutes.
	Reducing Post-harvest Losses in Mango in South Asia (Subramanian et al., 2015)	Treatment with hexanal (0.02%) more than doubles mangoes' shelf life (up to 17 days at room temperature and 26 days in cold storage conditions), enabling them to reach lucrative export markets. Incorporating hexanal in mango packaging to further improve its transport potential is under review.
	Pineapple	
Post-harvest Issue	**Research**	**Measures**
Occurrence of Internal browning	Basal Application of Fused Magnesium Phosphate (FMP) on the Incidence of Post-harvest Internal Browning of Mauritius Pineapple (Selvarajah et al., 1999)	Plants treated with FMP (250 kg/ha and 500 kg/ha) and stored for 1, 2, 3 and 4 weeks at 15^0 C after 3 days at room temperature had significantly lowered IB intensity.
Black rot in pineapple leading to post-harvest decay (*Thielaviopsis paradoxa* is the causal organism (fungal)	Use of Compounds generally Recognized as Safe (GRAS) for the Post-harvest Control of Thielaviopsis Fruit Rot of Pineapple (Ranawana, 2004)	This pathogen can be effectively controlled by the use of systemic fungicides. Acetic acid at a concentration of 3% is an effective alternative method to fungicides.

Table 3.6 (contd.): Research Conducted to Minimize Post-harvest Losses in Fruits and Vegetables in Sri Lanka

Post-harvest Issue	Research	Measures
Development of Internal Browning under the cold storage during sea shipment.	Effect of Calcium and Potassium Fertilizer Applied at the Time of Planting on the Control of Internal Browning under the Cold Storage of Mauritius Pineapple (Herath et al., 2000)	The application of calcium and potassium fertilizer at the time of planting could increase fruit calcium and potassium content while reducing the incidence of IB up to the fourth week of cold storage (15°C and 80-85% RH).
	Pre-harvest Calcium Spray in Incidence of Internal Browning in Pineapple (cv. Mauritus) during Cold Storage (Sarananda, 2008)	Spraying of 3g of calcium chloride on fruit one month after fruit being set as a single application
High post-harvest losses during sea shipment due to brown spots and internal browning	Extending the Storage Life while Maintaining Post-harvest Quality of Pineapples and Bananas with special reference to Modified and Controlled Atmospheric Storage (Wijeratnam, n.a.)	Spraying Calcium Chloride (1.3g per fruit) followed by post-harvest wax treatment to reduce the incidence and the severity of the internal browning in Mauritius pineapple.
Quality deterioration due to poor handling techniques	Post-harvest Handling of Mauritius Pineapple at Ambient Temperature (Fernando and De Silva, 2000)	Fruits were harvested with 10cm long stalk, transported and stored in plastic crates with crown end inverted and the waxed treatment should be done. (For short term pineapple storage in ambient temperature)

Table 3.6 (contd.): Research Conducted to Minimize Post-harvest Losses in Fruits and Vegetables in Sri Lanka

Guava		
Post-harvest Issue	**Research**	**Measures**
Increase shelf life of Guava	Application of Polysaccharide based Composite Film Wax Coating for Shelf Life Extension of Guava (Variety Bangkok Giant) (Wijewardane, (2013)	Edible wax solution (palm oil (3%), glycerol (30%), Sorbitan monooleate (tween 80) (2%) and guar gum (2%)) mixed with water in 1:1 ratio. Treatment extends the shelf life of guava up to 9 days under ambient condition (29-32^{0}C and 65%- 70% RH).
Other Fruits and Vegetables		
Post-harvest Issue	**Research**	**Measures**
White waxy scale has become a devastative pest for many fruits (passion fruit, coffee, mango, rambutan, mangusteen, lawulu, jambu)	A new threat to fruit cultivation in Sri Lanka (Pushpakumari et al., 2014)	Pruning of heavily infested branches, mechanically removing of scales and burning all infested parts with leaves under the tree.
Short shelf life of vegetables	Retail Mobile Stall for Extending the Shelf Life of Selected Fresh Fruits and Vegetables (Kumarasinghe, 2011)	Mobile retail stores developed by IPHT have cool temperature around 23^0–24^{0}C and RH 90% to 95% and the selected vegetables can be stored without quality deterioration for 7 days.
High wastage in Okra	Post-harvest Changes and Performance at Processing of Some Sri Lankan Vegetables (Sangasena, 1990)	Shelf life of bitter gourd can be extended up to 2 weeks by storing at a lower temperature and by packaging in polypropylene bags. Pods stored at 11$^+$. 2^o C in polythene showed the longest storage period of 7 days.

Table 3.6 (contd.): Research Conducted to Minimize Post-harvest Losses in Fruits and Vegetables in Sri Lanka

Post-harvest Issue	Research	Measures
	Evaluation of Different Types of Packages for Handling and Transportation of Vegetables (Jayathunge et al., 2011)	The nestable plastic crate (52.5x35.0x30.0 cm) was identified as the most suitable package for handling and transportation of tomatoes and the nestable plastic crate (60.0x42.5x30.0 cm) was identified as the most suitable package for other vegetables such as beans, cabbage, brinjals and curry chilli.
Improper packing and packaging reduce quality of fresh vegetables	New Consumer Packs Reduce Post-harvest Losses of Vegetables (Peris and Sarananda, 2005)	2kg of beans, leeks, carrot and lettuce packed in low density polyethylene bags (LDPE) (0.5 cm thickness) showed low post-harvest losses and this technology can also be used as an income boosting value addition method. Suitable packaging to be used as consumer packs for the supermarkets.
Loss of water after harvest, causing rapid wilting and yellowing and finally losing of saleable weight in leafy vegetables	Post-harvest Life of Two Leafy Vegetables is Affected by Harvesting Time of the Day (Senavirathna et al., 2009)	Leaves harvested in the evening exhibited better performance and manifested mainly by minimum weight loss, yellowing and longer shelf life. Wilting and post-harvest diseases were not observed during storage.
High post-harvest losses of leeks during transportation	Reduction of Post-harvest Losses in Leeks during Transportation using Wooden Bulk Packages (Wijewardane et al., 2014)	75cm X 45cm X 30cm size plastic crates with filling height 25cm showed better performance by reducing wilting, physical damage and weight loss by retaining higher visual quality.

Source: Author's Information from Reviewed Research Papers

CHAPTER FOUR

Review of Safety Issues of Fruit and Vegetable Supply Chains in Sri Lanka

4.1 Introduction

Fresh fruits and vegetables have recently been identified and confirmed as a significant source of pathogens and chemical contaminants that pose a potential threat to human health worldwide. Production of fresh fruits and vegetables entails activities such as farming, harvesting, post-harvest treatment and processing. Within all these activities, specific hazards that affect product safety and quality exist and it poses a risk for the consumer.

Food safety is developing into one of the most urgent issues confronted by the international community due to increasing globalization of trade in food. Generally, food safety is aided by four key words: food, hazard, toxicity and safety. Food safety has become a vital food quality attribute in the last decade. Food production, distribution and preparation constantly change to meet the consumers' demand while food and agricultural industries attempt their level to produce food as cheaply as possible for the highest satisfaction of consumers.

With increased trade in fresh and processed food, there is a growing concern about food safety issues in Sri Lanka. When exploiting the export potential for fruits and vegetables safety risk of these foods to meet international market requirement is necessary. It is important to maintain higher levels of quality and safety measures consistent with EU regulations and US Food and Drug Administration. Therefore, effective quality control systems are needed to fulfill the export market requirement for fresh and processed fruits and vegetables from Sri Lanka.

Safety issues are not only restricted to on-farm practices but also include post-harvest management practices regarding quality and safety concerns. Farm to table quality management systems include Good Agricultural Practice (GAP), Good Manufacturing Practice (GMP) and Hazard Analysis Critical Control Point (HACCP).

4.2 Consumers Perception on Safety of Fruits and Vegetables

Rodrigo in 2009 in a study with consumer perception on safety of vegetables and their willingness to pay found that most of the consumers purchase vegetables from supermarkets highly consider safety of vegetables while in other retail shops consumers consider moderately on safety of vegetables. All consumers in supermarkets are willing to pay an additional premium from the prevailing market price for safety of vegetables. The study further indicated that majority of the consumers highly hesitated to purchase cabbage, brinjal, capsicum, tomato and lotus root and kankun. The results indicate that majority of consumers' concern over safety is high and on average the Willingness to Pay (WTP) is relatively high. Therefore, steps have to be taken to implement a cost effective safety assurance

system for the higher satisfaction of consumers by the government with a separate market window to provide safe vegetables to consumers (Rodrigo, 2009). In order to obtain safe vegetables consumers practice washing of vegetables thoroughly before cutting vegetables and washing with salt water is practiced for leafy vegetables.

4.3 Food Safety Hazards in Fruits and Vegetables

Fresh fruits and vegetables can become contaminated by biological hazards such as pathogenic organisms including bacteria, viruses and parasites, chemical hazards and physical hazards.

4.3.1 Biological Hazards

Biological hazards in fresh produce occur due to micro-organisms such as bacteria, fungi (yeasts and moulds), protozoans, viruses and helminths (worms) which can also be termed as microbes. Micro-organisms capable of causing human disease may be found in raw produce. Sometimes they are part of the fruit and vegetable microflora as incidental contaminants from the soil and surroundings. In other instances, they are introduced into or on food by poor handling practices in agricultural production or post-harvest processes. The primary sources of microbial contamination of fresh fruits and vegetables are; human and animal faeces (e.g. untreated manure/faeces or municipal bio solids and sewage fluids), contaminated water (agricultural and processing water), contaminated soil, dust, surroundings and handling equipment and poor sanitary practices throughout the production chain (contamination by humans or animals) (Ecobichon, 2001; cited in Din et al., 2011).

4.3.2 Chemical Hazards

Fruits and vegetables can be contaminated with toxic chemicals from a variety of sources may include heavy metals, pesticides residues, contaminants and fungicides. Amongst all these pesticide residues are ranked the top safety issue (Kader and Roll, 2004; cited in Din et al., 2011). In certain countries, in addition to washing with water, chemical disinfectants are used to decontaminate the surface of fruits and vegetables. It was reported that major share of severe pesticide toxicity in human beings is caused by Organophosphate pesticides (Ecobichon, 2001; cited in Din et al., 2011).

Chemicals and single substances can pose a serious health hazard to the consumer if fresh fruit and vegetables are contaminated in significant concentrations. Contamination may be caused by either naturally occurring substances or by synthetic chemicals that may be added or are present during agricultural production or post-harvest treatment and further processing.

Presence of heavy metals such as arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr) in food is a dominant threat related to food safety. The extent of exposure of the country's population to food contamination caused by toxic heavy metals is not widely available.

4.3.3 Physical Hazards

Physical hazards are foreign material in product that can cause injury. The high moisture content and soft texture of fruit and vegetables make them susceptible to mechanical injury which can occur at any stage from production to retail marketing. A small scratch or cut on produce surface result in increased respiration rate, heat production and fasten the ethylene production. The fruit or vegetable ultimately end in senescence. Further, this damaged portion of fruit or vegetable serves as a suitable medium for microbial growth. Micro-organisms start to multiply causing rotting and microbial infestation. Quality deterioration that occurs leaves the produce completely unsafe for human consumption. Physically, contamination can result from contact with the soil; manure; irrigation water; faecal material from wild and domestic animals; farm and contaminated equipment use in fields, transport and distribution system; improper storage, packaging, display and preparation (Bihn and Gravani, 2006; cited in Din et al., 2011).

4.4 Pesticide Residues in Fruits and Vegetables

Like other crops, fruits and vegetables are attacked by pests and diseases during production and storage leading to damages that reduce the quality and the yield. In order to reduce the loss and maintain the quality of fruit and vegetable harvest, pesticides are used together with other pest management techniques during cropping to destroy pests and prevent diseases. Pesticides are human-made and naturally occurring chemicals that control insects, weeds, fungi and other pests that destroy crops. Pesticide application is still the most effective and accepted means for the protection of plants from pests and contributes significantly to enhance agricultural productivity and crop yield. However, pesticides are toxic substances and persistent in character. The problem of contamination of food sources, especially vegetables by pesticide residues constitutes one of the most serious challenges to public health.

The presence of pesticide residues is a concern for consumers because pesticides are known to have potential harmful effects to other non-targeted organisms than pests and diseases. Major concerns are their toxic effects such as interfering with the reproductive systems and foetal development as well as their capacity to cause cancer and asthma. Some of the pesticides are persistent and therefore remain in the body causing a long term impact (Gilden et al., 2010; cited in Keikotlhaile and Spanoghe, 2011).

Fewer farmers intentionally apply pesticides on harvested or crops about to be harvested as a strategy to extend storage lifespan of the harvest. Conversely, Sri Lanka's common farming practice heavily depends on mono cropping and monoculture, which usually trigger pest attacks and plant diseases; hence extensive agrochemical use is inevitable. Very often farmers postulates that higher the usage of fertilizer, higher the yield, though reality differs. Over usage of synthetic fertilizer results in subsequent leaching while polluting the groundwater, a phenomena common in many agricultural areas.

According to the studies on pesticide usage of vegetable farmers by Chandrasekara et al. (1985) and Padmajani et al. (2014) highlighted malpractices and misuse of pesticides by farmers. It is observed that most of the farmers harvest their crops within 7-14 days after the final application of pesticides. Some farmers go directly to the dealer mainly because of the convenience instead of consulting extension officers. Fewer farmers consult their neighbours to decide what pesticide is to be used. Pesticide manufacturing companies have more influence on the farming community than the government does in terms of pesticide selection and usage. Farmers tend to overdose pesticides surpassing the recommended level of the Department of Agriculture. Most of the farmers apply pesticides to their crops prior to incidence of pests primarily owing to ignorance. Pesticides are applied rampantly disregarding the recommended dosage and instructions given on the labels and harvesting is practised without observing the waiting periods. For bitter gourd, ridge gourd or snake gourd, the farmers have to apply pesticides closer to harvesting time as these vegetables are highly prone to pest attacks. However, if the recommended pre-harvest interval for harvesting is observed the crops will be over mature. Therefore, harvesting is practiced in two to three days after application of pesticides (Chandrasekara et al., 1985). Moreover, harvesting is further hastened if market prices are lucrative.

Dissanayake (2009) in a study with farmers' behaviour and habits with pesticide usage found that the farmers lack effective disposing methods for the empty containers and poor disposing methods practiced by farmers lead to contamination of environmental resources. The above issues can be attributed to farmers' little knowledge on safe and efficient use of pesticides. As a result the consumers fall prey to improper use of pesticides. Therefore, education and training of these farmers is key to resolve the associated issues in pesticide management.

Various forms of human-induced food adulteration during farm and industrial production and marketing escalate complexity. One of the important human-induced safety concerns is the presence of pesticide residues in food. Therefore, the issues related to pesticides can be listed as follows;

- use of overdose of pesticides
- application of pesticides at shorter intervals
- non-compliance to the withholding period (minimum duration between last application and harvest)
- application of cocktail of pesticides (mix of two or more pesticides together)
- ignorance of the users
- lack of motivation
- lack of proper and expanded media campaign
- exploitation by the agents of the pesticide suppliers
- absence of an effective monitoring system on pesticide usage

4.4.1 Pesticides' Fate after Application to Fruits and Vegetables

Fate refers to the pattern of distribution of an agent, its derivatives or metabolites in an organism, system, compartment or (sub) population of concern as a result of transport, partitioning, transformation or degradation (OECD, 2003). After pesticides are applied to the crops, they may interact with the plant surfaces, be exposed to the environmental factors such as wind and sun and may be washed off during rainfall. The pesticide may be absorbed by the plant surface (waxy cuticle and root surfaces) and enter the plant transport system (systemic) or stay on the surface of the plant (contact). While still on the surface of the crop, the pesticide can undergo volatilization, photolysis chemical and microbial degradation. Volatilization of the pesticide usually occurs immediately after application in the field. Photolysis occurs when molecules absorb energy from the sunlight resulting in pesticide degradation. The indirect reaction can also be caused by some other chemicals being broken by the sunlight and their products reacting with pesticides in turn. Some pesticides may be degraded by microbial metabolism. Micro-organisms can use pesticides as nutrients thereby breaking them into carbon dioxide and other components (Holland and Sinclair, 2004; cited in Keikothaile and Spanoghe, 2011). The products formed may be less or more toxic than the parent chemical. Rain wash off can also be very important when it occurs shortly after application.

4.4.2 Pesticide Residue Analysis of Fruits and Vegetables

Pesticide residues are the deposits of pesticide active ingredient, its metabolites or breakdown products present in certain components of the environment after its applications, spillage or dumping. Residue analysis provides a measure of the nature and level of any chemical contamination in the environment and of its persistence. Pesticides must undergo extensive efficacy, environmental and toxicological testing to be registered by governments for legal use in specified applications. The applied chemicals and/or their degradation products may remain as residues in the agricultural products, which becomes a concern for human exposure. Selected sampling programmes can be used to investigate residual levels of pesticide in the environment, their movement and their relative rates of degradation (Dasika et al., 2012).

There is no long term systematic pesticide monitoring programme in Sri Lanka and a very few organized studies have been carried out on contamination of food and water by pesticides.

Mubarak (2014) and Zaneer (1998) in a study of pesticide residual trials with leafy vegetables (kankun, sarana, mukunuwenna and gotukola) in Sri Lanka to check the presence of Endosulfan, Carbofuran, Chlorpyriphos, Quinalphos, Profenofos identified that immediately after spraying (in two hours) of pesticides, all the insecticides except Carbofuran were detected at high levels (20-65mg/kg) in all leafy vegetables studied. After 14 days of spraying it was low (0.5mg/kg) except in *gotukola* (5.5-11 mg/kg). It explained further that dip washing and heating in water to 80^0C did not significantly lower the residue levels.

Dissanayake (2009) studied pesticide residue analysis of tomato by using Gas Chromatography/Mass Spectroscopy. The study found that Carbofuran, Mancozeb, Antracol, Polyram and Mancozeb and Carbaryl were present in both peel and flesh of tomatoes.

A study conducted on the Mahaweli River at Peradeniya has found pesticide residues (Illeperuma, 2000). Earlier a study conducted on pesticides by using gas chromatography and had found hydrocarbon residues in fruits and vegetables (Ramasundaram et al., 1979; cited in Illeperuma, 2000).

Marasinghe et al. (2011) in a research conducted during the period 2001-2009 using 31 rice samples, 1,043 vegetable samples and 554 surface washed vegetables reported an analysis for organophosphates with 19, 125 and 15 detections of residues respectively. Chlorpyrifos, profenofos and diazinon were the most frequently detected organophosphates in rice, vegetables and surface washed vegetables with concentrations in the range of 2.6 x 103 to 5.0 x 106 ng/kg, 5.0 x 103 to 5.0 x 106 ng/kg and 1.2 x 104 to 1.0 x 105 ng/kg, respectively.

Using past data, it can be concluded that food commodities, particularly vegetables in Sri Lanka could contain pesticide residues at low levels but could reach unacceptable levels occasionally. Therefore, it is recommended that regular residue monitoring is necessary to identify the areas and crops contaminated with unacceptable residue levels which would ultimately lead to alter the use pattern of pesticides to minimize the dietary exposure. For this it is important to select more sensitive analytical techniques and equipment to reach the low limit of quantification (LOQ) than defined MRL while using the accreted laboratories for pesticide residue analysis to ensure the reliability of analytical results.

4.4.3 Permissible Limits of Pesticides

The total dietary intake of pesticide residues that remain on agricultural commodities are known as toxins and therefore it is desirable to reduce these residues. Maximum Residue Levels (MRLs) refer to the upper legal levels of a concentration for pesticide residues in or on food or feed based on good agricultural practices and to ensure the lowest possible consumer exposure. MRLs have been widely adopted by countries around the world and sometimes lead to confusions as residue acceptable levels differ from country to country. Developed countries, compared to developing ones have adopted much higher standards. In the case of Sri Lanka, the use of pesticides is governed by the Control of Pesticides Act of 1980.

Maximum residue levels are the highest levels of residues expected to be in the food when the pesticide is used according to authorized agricultural practices (EFSA, 2010). The MRLs are always set far below levels that are considered safe for humans. It should be understood that MRLs are not safety limits, a food residue can have higher level than MRL but can still be safe for consumption. Safety limits are assessed in comparison with acceptable daily intake (ADI) for short term exposure or acute reference dose (ARD). MRLs are subjected to legal requirements in most of the

countries. The adverse impact of pesticides became a matter of international concern and the United Nations (UN) Organization established a commission to determine guidelines to safeguard consumers and to issue recommendations in that regard. The commission "Codex Alimentarius Commission" formed in 1962 comprises about 120 member nations (including Sri Lanka). The Codex Committee on Pesticide Residues (CCPR) is one of the several committees of this commission. Government representatives in this committee are concerned with the impact on food quality and residues of pesticides. The international code of conduct on the use of pesticides was agreed upon. One of its aims is agreement on internationally acceptable maximum limits of pesticide residues in food to safeguard consumers. An issue of "Guide to Codex Maximum Limits of Pesticide Residues" was published in 1978 by FAO/WHO.

The Government Regulation made by the Minister of Agriculture in 2016 under section 26 read with section 20 of the Control of Pesticides Act No. 33 of 1980 has described the MRLs for the Pesticides and crops. The time limit between the use of pesticides on the food crops and the harvest of that food crop are specified in that.

4.5 Fruit Ripening and Safety Issues

Using synthetic chemicals to induce ripening of climacteric fruits such as mango, banana, papaya, tomato and jackfruit is a persistent problem in Sri Lanka. Fewer non-climacteric fruits such as pineapple are also exposed to ripening chemicals. For commercial agriculture, induced fruit ripening is recommended all over the world for uniform ripening, taste and quality. In developed countries, ethylene gas is used to induce ripening of climacteric fruits. In Sri Lanka, different types of liquid plant growth regulators containing ethephon as active ingredient are sprayed on the fruits or the fruits are dipped in a solution of ripening chemicals.

Fruit ripening is a natural process in which the fruit goes through various chemical changes and gradually become sweet, flavoured, coloured, gets soft and become palatable (Brady, 1987). To meet consumer demand and other economic factors, different methods of artificial fruit ripening are in practice in Sri Lanka instead of the conventional ripening techniques such as heat, light and smoking. Artificial ripening accelerates ripening, but affects the nutritional quality of the fruits. Consumption of fruits becomes a risk due to artificial ripening by different toxic chemicals.

Among the widely used artificial ripening agents, ethylene and methyl jasmonate are reported as non-toxic for human consumption; however, they are relatively expensive. In many developing countries, low-cost chemicals such as calcium carbide, ethylene glycol and ethephon are reported to be commonly used to artificially trigger the ripening process (Islam et al., 2016).

Transporting and distributing fruits from the farmers' orchards to consumers' baskets can take several days. During this period the naturally ripened fruits may become over ripen and inedible. Part of naturally ripened fruits can also be damaged due to harsh transportation conditions. It indeed increases economic loss for the

fruit sellers and therefore, to minimize the loss, fruit sellers sometimes prefer collecting fruits before full maturity and artificially ripen fruits before selling to the consumers.

The literature reveals that most of the ripening agents are toxic and their consumption can cause serious health problems such as heart disease, skin disease, lung failure and kidney failure. Scientists have also reported that regular consumption of artificial ripened fruits may cause dizziness, weakness, skin ulcer and heart related diseases (Hakim et al., 2012). Calcium carbide is alkaline in nature and irritates the mucosal tissue in the abdominal region.

Amarakoon et al. (1999) studied the optimum dose of calcium carbide required to induce ripening of 'Velleicolomban' and 'Willard' mangoes in Sri Lanka due to use of high dose of calcium carbide commercially which results in inferior quality that are unacceptable to the consumer. Mango fruits ripe unevenly on the tree and natural ripening can be very slow and unpredictable. Hence, to overcome these problems certain chemicals are used to induce ripening. The optimum dose of calcium carbide required to induce ripening of mangoes to achieve overall acceptability was found to be 1g/kg fruit. At this level of calcium carbide, there was no difference in the total soluble solids content, titratable acidity and taste between artificially and naturally ripened fruits (Amarakoon et al., 1999). Carbide should be wrapped in newspaper and placed at the bottom of the pile so that it does not come into contact with the fruit.

Research conducted in Bangladesh found that the cases of stomach discomfort after consuming carbide ripened mangoes (Siddiqui and Dhua, 2010). Calcium carbide contains cancer-causing properties and that cause neurological disorders. It can result in tingling sensation and peripheral neuropathy. A significant number of pregnant women who consumed fruit ripened with carbide had delivered children with abnormalities (Rahim, 2012; cited in Hossain et al., 2015). Consumption of carbide-ripened fruits is extremely hazardous for health, mainly for the nervous system. Acetylene, generated from carbide reduces oxygen supply to the brain. At acute stage it causes headache, vertigo, dizziness, delirium, seizure and even coma. In the long term it may produce mood disturbance and loss of memory. Immediately after consumption abdominal pain, vomiting and diarrhea may be experienced. Other toxic effects include skin burns, allergy, jaundice and carcinogenic potential (Fattah and Ali, 2010; cited in Hossain et al., 2015).

Chemicals are commonly used for artificial ripening of fruits in Sri Lanka. Although Section 26 of the food (labeling and miscellaneous) regulation of 1993 explicitly prohibits the use of calcium carbide, this chemical is commonly used by collectors and traders for the production of acetylene to induce fruit ripening. Calcium carbide is widely used for the ripening of mangoes, papayas, durians and bananas in Sri Lanka. Calcium Carbide treatment is banned as it contains traces of arsenic and phosphorous hazardous to human beings. Acetylene is not harmful if properly used. The dosage used by traders normally exceeds the recommended level of 1g/kg of fruit. The method used in the application of carbide is also hazardous to health, in

that carbide pieces can find themselves among the heaps of fruit. Excessive use of commercial grade calcium carbide results in direct contact with the fruit causing contamination with carcinogenic compounds such as arsenic and phosphorus hydrides. 'Ethrel' is a harmless ripening-induced chemical which releases ethylene. This compound which is recommended by the Department of Agriculture in Sri Lanka is slowly gaining popularity among fruit collectors and traders for ripening bananas, mangoes and avocados (Fernando, 2006).

ITI recommends to use a minimal amount of ethrel diluted in water (1 ml per litre of water) and to place the containers filled with the solution around the room. The fruits are then stacked in the room and sodium hydroxide is added to the mixture. All ventilation to the room is then blocked off and the fruits will ripe in two days in the gas that is released.

4.6 Current Status of the Standards for Fruits and Vegetables and Testing Infrastructure

WTO's agreement on application of Sanitary and Phytosanitary (SPS) measures and agreement on Technical Barriers to Trade (TBT) have significantly altered the international environment for food safety. Failure to meet the standards and exporting poor quality food and that is unfit for consumption, to developed countries leads to rejection of shipments. SPS standards regulation in Sri Lanka has still not reached the international SPS standards particularly in terms of sanitary standards for fruits and vegetables. Further, interventions at the production/growing stage to ensure quality and safety is minimal.

The Food Act of Sri Lanka is being revised and new standards are being introduced or the existing ones are being upgraded in line with international standards. Recently, Registrar of Pesticide has formulated Maximum Residue Levels for pesticides stipulated by law for fruits and vegetables to prohibit sale of fruits and vegetables containing residues of pesticides in excess of the permitted limits.

WTO regulations for application of pesticides, insecticides and weedicides and codex Alimentations Commission's SPS measures for pesticide limits should be followed to reduce the risk of contamination. Time of harvesting and application of pesticide or fungicide should be considered to reduce the risk of high level of chemical residue remaining in the fruit or vegetable that make it unfit for consumption.

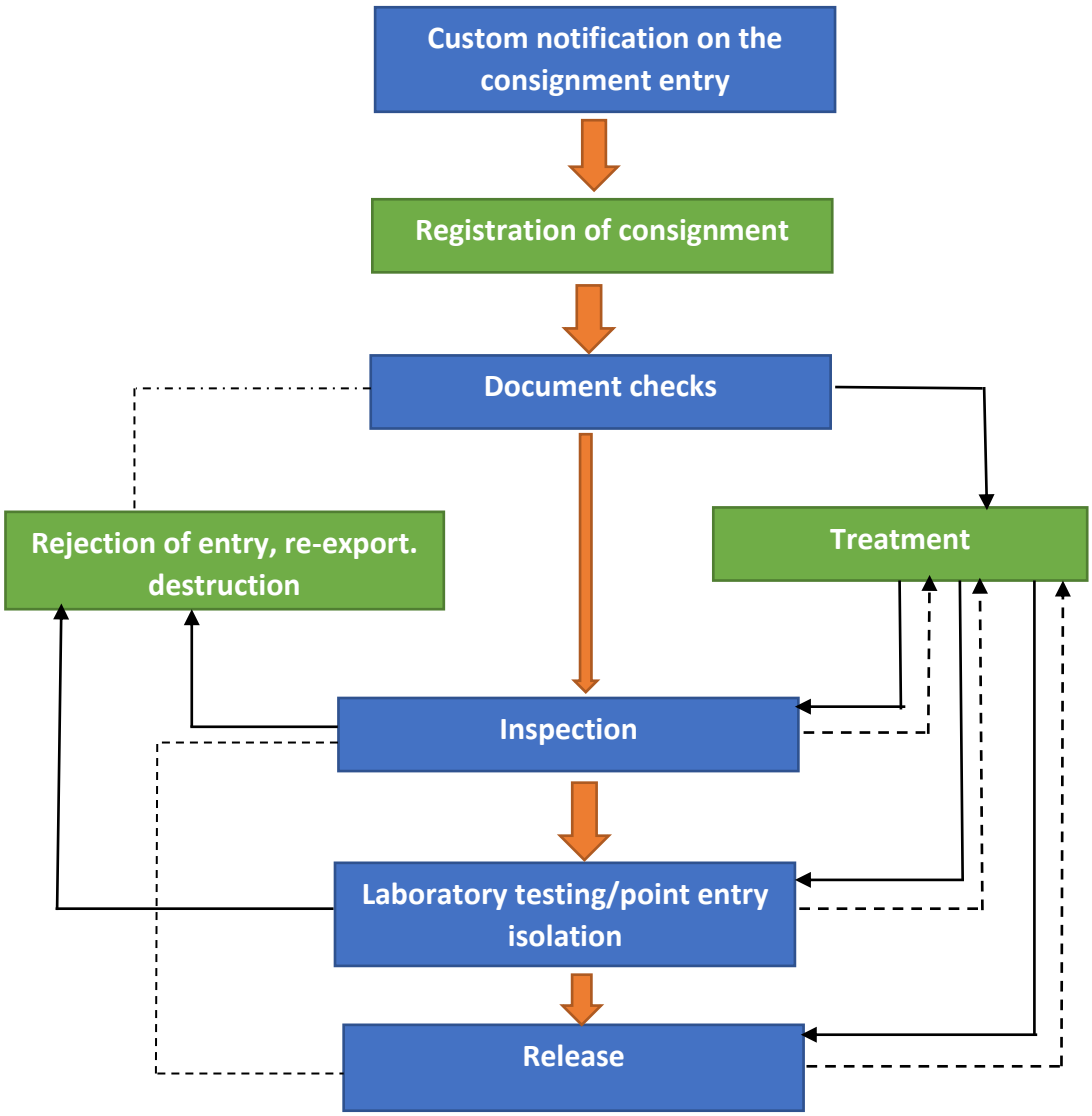
Establishment of GAP, GMP, GHP and HACCP programme including SPS measures could be an effective tool to cover all aspects of growing, harvesting, packing, transportation, processing, distribution of fresh fruits and vegetables. Assistance from and collaboration between academic institutes, public health authorities, food control agencies, trade organizations and private sector in developing HACCP and Global GAP system for fresh fruits and vegetables industry is necessary for sustainable production and to minimize potential health hazards due to the contamination as well to improve the export potential.

The testing infrastructure in the country falls under different Ministries. At present the two leading institutes that provide standards certification and testing facilities for exporters (eg. HACCP) are Sri Lanka Standards Institute and the Industrial Technology Institute which fall under the purview of the Ministry of Technology and Research. In addition, three other laboratories fall under the purview of the Ministry of Health. The labs of the Registrar of pesticides and the labs of the plant quarantine division fall under the purview of the Ministry of Agriculture. The Government Analyst Department which falls under the Ministry of Justice also conducts food testing. Private companies (eg. SGS Lanka Pvt Ltd) provide testing and certification facilities to exporters as well (Gunaruwan and De Silva, 2014).

4.6.1 SPS Standards for Fruits and Vegetables

According to the provision of Plant Protection Act no. 35 of 1999, the regulations are observed by the National Plant Quarantine Service (NPQS) of the Department of Agriculture in exporting and importing fruits and vegetables. For imports of fruits a phytosanitary certificate issued by an authorized officer of the Plant Quarantine Service of the country of origin is compulsory. All the importers of fruit products are subjected to the regulations made under the Plant Protection Act.

- No plant or plant product can be imported without a valid permit obtained from the Director General Agriculture.
- The consignment should not contain plant debris as packaging materials.
- Importation of fruit products are prohibited from tropical American countries.
- Fruit should be free of leaves and branches and also they should be securely packaged in cardboard or plastic cartons. Every consignment of fruit shall be transported to Sri Lanka by sea freight in cold storage at a temperature of 0^0C – 2.2^0C (32^0 – 36^0F).
- Caramel coated apples are not allowed to be imported from the USA.

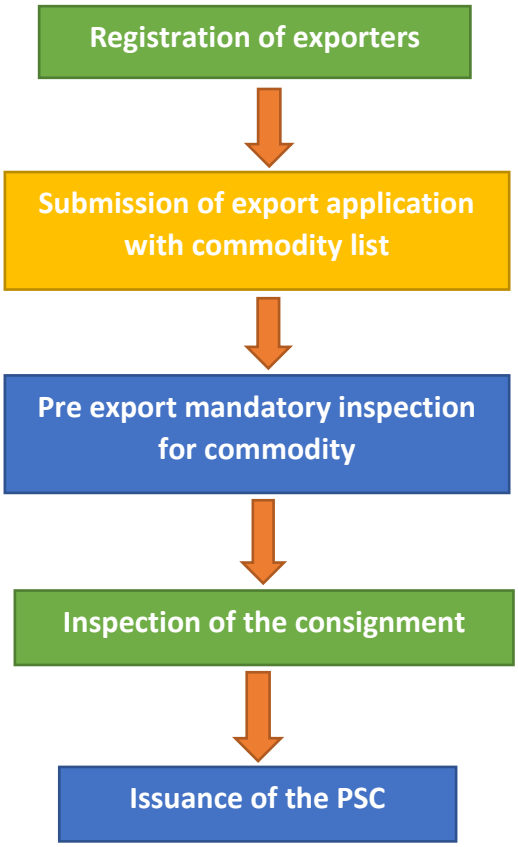


Source: HARTI Survey Information from National Plant Quarantine Service, Department of Agriculture

Figure 4.1: Phytosanitary Procedure for Importing Plants and Plant Products

When exporting fruits and vegetables, the consignment should arrive at the airport six hours early for cooling. During this period quarantine and the custom procedures are undertaken. When exporting plants and plant products plant quarantine requirements of the importing country should be met and the phytosanitary certificate issued by the NPQS should be obtained. PSC is issued;

- If the consignment is free from pest and diseases
- The consignment complies with the quarantine regulations of the importing country
- Consignment should be exported within 14 days from the date of issuing the phytosanitary certificate



Source: HARTI Survey Information from National Plant Quarantine Service, Department of Agriculture

Figure 4.2: Phytosanitary Procedure for Exporting of Plants and Plant Products

In September 2016, an audit by the EU to evaluate control of pesticides in food of plant origin was conducted. When exporting to those countries, it is important to have GAP certificate from the DOA. NPQS only allow to export leafy vegetables with GAP certificate to Europe countries with effect from 15th March 2017. Markets of Maldives and the Middle East do not require stringent quality standards and quality certification.

The Table 4.1 explains the sample size inspected at the NPQS to issue the PSC according to the number of total boxes exported in each consignment.

Table 4.1: Sample Size Inspected to Issue PSC

Number of Boxes/Cartons	Sample Size
1-10	3 boxes (80 pieces)
11-50	10 boxes (100 pieces)
51-500	30 boxes (300 pieces)
501-2000	50 boxes (500 pieces)
2001-5000	100 boxes (1000 pieces)

Source: HARTI Survey Information from National Plant Quarantine Service, Department of Agriculture

4.6.1.1 SPS Issues Faced by Fruit and Vegetable Sector

1. Errant pesticide and fertilizer use, poor post-harvest practices

Quality and safety of fruits and vegetables produced in Sri Lanka suffer due to improper pesticide and fertilizer use, poor handling/sorting during collection, inappropriate storage and transport.

2. Lack of awareness and training

There is poor awareness of international and export market SPS standards requirements and the importance and benefits of adhering to these standards among all stakeholders in the fruits and vegetable value chain. Training on SPS standards and how to meet them is rare and not regular. Lack of trained officials is a barrier that affects safety and quality of the exported agricultural products.

3. Lack of proper pest risk analysis system

This process helps avoid or reduce the probability of entrance or establishment of the pest into the country. This is essential to help protect the country's agriculture from impending damages caused by harmful (quarantine) pests that come along with imported commodities. Lack of expertise in pest risk analysis is a potential trade constraint.

4. Poor coordination among stakeholders

Institutional mechanism responsible for SPS management is highly fragmented and coordination and cooperation among the respective institutes is poor.

5. Lack of understanding on the current capacity of the testing infrastructure

The existing laboratory facilities are owned by the Government and they fall under the purview of different Ministries. Lack of coordination and cooperation among laboratories and lack of awareness on each other's strengths and weaknesses is observed. The local facilities are inadequate to meet the testing and certifying of SPS standards required for exporters in the country. Hence, testing is carried out outside the country, a procedure which increases the cost and triggers delays (Gunaruwan and De Silva, 2014).

4.6.2 HACCP Standards

Requirement for food safety is applicable throughout the supply chain from producer/processor/wholesalers/retailers with all intermediaries such as equipment manufacturers, suppliers of cleaning agents, packaging producers, transport and storage operators. Sri Lanka has introduced various measures including the introduction of Hazard Analysis Critical Point (HACCP) systems for fresh and processed food products through the application of ISO 22000 to control and reduce any food safety hazards to an acceptable level.

ISO 22000 standards have been introduced in year 2005, which address food safety management systems of food sector and to enhance customer satisfaction through

the effective control of food safety hazards including processed for updating the system. This helps build a safe system throughout the food chain. This is basically a combination of ISO 9001 quality management system and HACCP standards and a few more (Jayasinghe, 2009).

HACCP is a system of food safety control based on a systematic approach to the identification and assessment of hazards associated with food operations and the definition of means for their control. This approach focuses on prevention and control and is advocated for every stage in the food chain from primary producers to the final consumer. The application of the HACCP system consists of a logical sequence of 12 steps encompassing seven basic principles which can be implemented in any food industry.

4.6.3 Good Agricultural Practices (GAP) for Fruits and Vegetables

As a solution for safety and quality issues in agriculture products, the Good Agricultural Practices (GAP) programme was introduced in January 2015. Under this programme, the application of fertilizer, pesticide and weedicide, harvesting, processing, transportation, grading, packing, value addition, labeling, distribution and storage processes will be monitored by the Department of Agriculture. If farmers adopt recommended methods, a certificate will be issued. Farmers have to register for the programme before the start of the cultivation season. The programme was initiated to target agriculture exports and will be expanded to supermarkets and ordinary markets. Forty Counselors in Agri-business (CAB officers) and 40 technical assistants have been appointed by the Department of Agriculture, who are responsible for monitoring and promoting this programme among farmers.

This was authorized for adoption as Sri Lanka Standard by Sri Lanka Standards Institution (SLSI) on 23/06/2016 (SLS 1523-1:2016). This will help control microbial, chemical and physical hazards associated in all stages from production to packaging of fruits and vegetables. This standard should be used in conjunction with the SLS 1412 – Code of Hygienic Practice for Fruits and Vegetables and the SLS 1465-Code of Practice for Use of Pesticides.

When chemicals or pesticides are used they should be in accordance with relevant legislations including the Regulation made under the Food Act No. 26 of 1980, Consumers Affairs Authority Act No. 09 of 2003 and the Control of Pesticides Act No. 33 of 1980.

SLS 1524: 2016 provides specific guidelines which will help minimize microbial and chemical hazards of fresh leafy vegetables from production to consumer level. This code is also subject to the restrictions imposed under the Food Act No. 26 of 1980.

4.6.4 Organic Standards and Certification for Maintaining Quality for Export Market

A major market channel for organic produce in Sri Lanka is the export market. Bulk of the volume of organic agricultural products is exported. Major export destinations include European countries, USA, Japan and Australia. The market in the Middle East is also a growing one. A few private sector organizations and non-governmental organizations are responsible for exporting organic food (Kariyawasam, 2007; cited in Vidanapathirana and Wijesooriya, 2014). Organic certification (external certification) is required to access distant and international organic markets. This is practiced on the basis of organic standards. For meeting the requirement of the organic export sector in Sri Lanka, certification is carried out by foreign certification agencies. Two such certifying organizations (Control Union and Institute for Market Ecology-IMO) involved in organic certification in the country. Organic is a form of labeling system granted for ecological production when the whole process is certified by an accredited third party organization. Without a third party guarantee on the compliance of set international standards on organic production methods, a product cannot be labeled, termed or called as organic (Ranaweera, 2008; cited in Vidanapathirana and Wijesooriya, 2014).

The certification covers the whole chain of activities starting from production to processing, but the minimum requirement for export is that it must meet the legal standards of the country of import. Certification leads to consumers trust in organic production system and products. Certification offers organic farming a distinct identity and credibility and makes market access easier (Prakash, 2003; cited in Vidanapathirana and Wijesooriya, 2014).

Sri Lanka Standard Institute has developed the National Standard; SLS 1324: Sri Lanka Standard for Organic Agriculture Production and Processing, in compliance with the EU requirements. These standards have been formulated based on guidelines or basic standards provided by International Federation of Organic Agriculture Movement (IFOAM), Codex Alimentarious and National Association for Sustainable Agriculture Australia Limited and LOAM (Lanka Organic Agriculture Movement). These standards prescribe the methods of production, processing, handling, storage and transportation of organically produced agricultural products. A standard for organic agriculture defines how production system be managed, covering all aspects such as soil fertility and pest control with emphasis on proper recording and labeling. According to the country of import, the exporting companies have to follow different organic standards and the certification bodies operate in that particular country perform inspection and certification according to those standards. For the export market, the quality of the organic food products needs to be assured from the production to marketing. Hence, the exporters have to monitor the entire supply chain to assure whether the required standards for certified products have been reached. Companies use different procedures to assess the quality of products (Vidanapathirana and Wijesooriya, 2014).

Procedures followed to assure whether farmers practice organic farming in a proper manner

- Internal control systems practiced by the company
- Extension services provided by the company via field level extension officers
- Random inspections by the field staff
- Improved and well equipped laboratories for quality control
- Samples are sent to other countries for testing

4.7 Institutional Environment to Monitor Food Safety

Sri Lanka Food Act No.26 of 1980 is the main legislative document covering food safety within the country. The Food Act is basically implemented through Director Health Services and through local authorities and MOH offices of the region. Twenty seven regulations are issued under the Food Act addressing different aspects of food and food safety.

4.7.1 National Regulations on Quality and Safety of Food

Sri Lanka Food Act No. 26 of 1980 has two amendments which were made as of Food (Amendment) Act No. 20 of 1991 and Food (Amendment) Act No. 29 of 2011 to address diverse aspects of food administration, legal proceedings and regulations in controlling of local food supply. Food Act refers to the domestic food trade, only for food products not for agricultural produce. Therefore, the Act does not cover the whole spectrum of farm to table continuum along the food chain.

The Food (amendment) Act No. 20 of 1991 explains many aspects of food safety requirements based on different types of food. The Act is to regulate and control the manufacture, importation, sale and distribution of food within Sri Lanka.

4.7.2 Role of Consumer Affairs Authority in Assuring Quality and Safety of Food

Consumer Affairs Authority (CAA) is the apex government organization mandated to protect consumers' interest and to ensure fair market competition in Sri Lanka. It has been established under the Consumer Affairs Authority Act No. 09 of 2003. The Act has laid down legal provisions empowering CAA to take necessary action to safeguard the interests of consumers while maintaining effective competition among suppliers of products.

The Consumer Affairs Authority Act No. 09 of 2003 was designed to protect the interest of the consumers and it came into effect with the establishment of the Consumer Affairs Authority falling under the Ministry of Industry and Commerce. It carries out legal proceedings in food controlling in reference to the legal provisions made by food regulatory acts (Food Act and SLSI Act). Import of food items is regulated by Import Export Control Act No.1, 1969, Food Regulations 2001 and Customs Ordinance and Customs Regulations.

The CAA in its food controlling role exerts the services of,

- Handling of consumer complaints
- Control of abusive trade practices
- Consumer education
- Empowerment of consumers
- Promotion of competition
- Market research and information

However, in food regulatory activities in Sri Lanka, CAA does not become as prominent as it lacks the required infrastructure of food controlling (e.g. laboratory facilities, analytical services, inspection services).

4.7.3 Sri Lanka Standard Institute

The Sri Lanka Standards Institute (SLSI) prepares and publishes standards which are voluntary and it has no authority to make their standards mandatory. Currently Sri Lanka Standards are available for only a limited types of fruits and vegetables; table potatoes, big onions, red onions, fresh bananas, fresh tomatoes and pineapples. Sri Lanka Standard Institute formulated Sri Lanka Standard Specifications (SLS) for canned, processed fruits and vegetable products export from Sri Lanka and make recommendations to the Department of Sri Lanka Customs. This scheme is based on the Gazette notification No. 1844/9 of 08 January 2014 under the Imports and Exports Control Act No.1 of 1969**.**

SLSI prepares standards in forms of product certifications and system certifications in relation to food industry. SLSI has imposed compulsory standards for seven food product categories locally produced in Sri Lanka including fresh fruit cordials, fruit cordial concentrates, fruit squash concentrates and fruit syrup concentrates, Ready-to-serve (RTS) fruit drinks. The product inspections for those products are conducted by SLSI in collaboration with the Department of Customs. If any product is found to be not in conformity with prescribed standards SLSI may take action to get products re-processed under supervision to return the consignment to exporting country or else to dispose it in an appropriate manner with assistance of the Department of Customs and Ports Authority (Madusanka, n.d).

4.7.4 Food Inspection Service under Food Control Administrative Unit (FCAU)

Basically, the import inspections and the peripheral food inspection services are handled by FCAU in inspections of national food controlling. For food importations the Food and Drug Inspector is in charge of inspection services at ports for ensuring the compliance of imports to local regulations. The peripheral food inspection service is an important concern in local food controlling as it is being responsible for inspections and auditing of a number of food operating bodies island wide. FCAU has the legitimate mandate only to control items that are of food products, not agricultural products.

The regional food inspectors of PHIs have been directed to conduct food inspections. The samples drawn are sent to food labs and the legal proceedings can be made only

by the authorized officers recognized by the Food Act. Further, if PHIs need higher order assistance in their duty, support is derived from Food and Drug Inspectors appointed for each district.

The official inspection service under the FCAU lacks satisfactory coordination and integration with other government agencies of the local food chain. Especially the PHIs have no legal mandate to inspect the conditions of agricultural produce and their supplies. Also, the peripheral food inspectors of PHIs, have to accomplish a wide spectrum of work load in their duty pertaining to a large locality.

The FCAU has the legitimate mandate only to control items of food products, not agricultural produce. For instance, the regulation of pesticide application, artificial ripening practices, plant quarantine, phytosanitary inspections, international trade of fresh fruits, vegetables and tea products are out of the mandate of central food control administration and integrated approach for whole food chain does not exist (Madusanka, n.d).

The national food controlling has been scattered among diverse agencies of ministries. Therefore, the local food control mechanism does not have a farm to table approach.
A common drawback in food inspection is the presence of the multiple agency system of local food control system.

4.7.5 National Food Safety Policy

Food safety has been a major concern in food system. However, majority of the regulations related to food safety were derived from the Food Act of 1980. There is a need for up–to-date food safety which attempts to address by the policy. A national policy on food security is already been drafted.

4.8 Implementation of Food Act

4.8.1 Food Advisory Committee

The Food Advisory Committee in Sri Lanka, appointed under the Food Act Controller, regulates all administrations of the Food Act, food related policy issues and new developments. Food advisory committee (FAC) consists of the representatives from the agencies implementing the different aspects of the Act. It consists of authoritative representatives for food administration, national health, Sri Lanka Customs, Colombo Municipal Council, animal health and related food production institutes and several other members nominated by the minister.

As per to the Food (Amendment) Act No. 26 of 2011, FAC comprises 25 members as follows.

(a) ex-officio members:

1. Director General of Health Services – Chairman

2. Director –in -Charge of Food Control Administration – Secretary
3. Two Deputy Director General of Health Services-in-charge of public Health Services
4. Two Assistant Directors of the Department of Health services-in-charge of Food Control Administration
5. Govt. Analyst or his nominee
6. Director General of Customs or his nominee
7. Director General of Consumer Affairs Authority or his nominee
8. Director General of SLSI or his nominee
9. Director General of Department of Commerce or his nominee
10. Director General of Department of Animal Production and Health or his nominee
11. Chief Medical Officer of Health of Colombo Municipal Council (CMC)
12. City Analyst of CMC
13. Food Commissioner or his nominee
14. Nutritionist from Medical Research Institute (MRI)
15. Legal Officer of the Ministry of the Minister to whom the subject of health is assigned

(b) nominated members:

1. An officer nominated by the secretary to the Ministry of the Minister to whom the subject of Local Government and Provincial Councils
2. A Food Technologist nominated by the Minister
3. A Food Microbiologist nominated by the Minister
4. A Food Scientist nominated by the Minister
5. A member nominated by the Minister who shall represent commercial interests relating to food
6. A member nominated by the minister who shall represent industrial interest relating to food
7. Two members nominated by the Minister to represent the food related interests of consumers

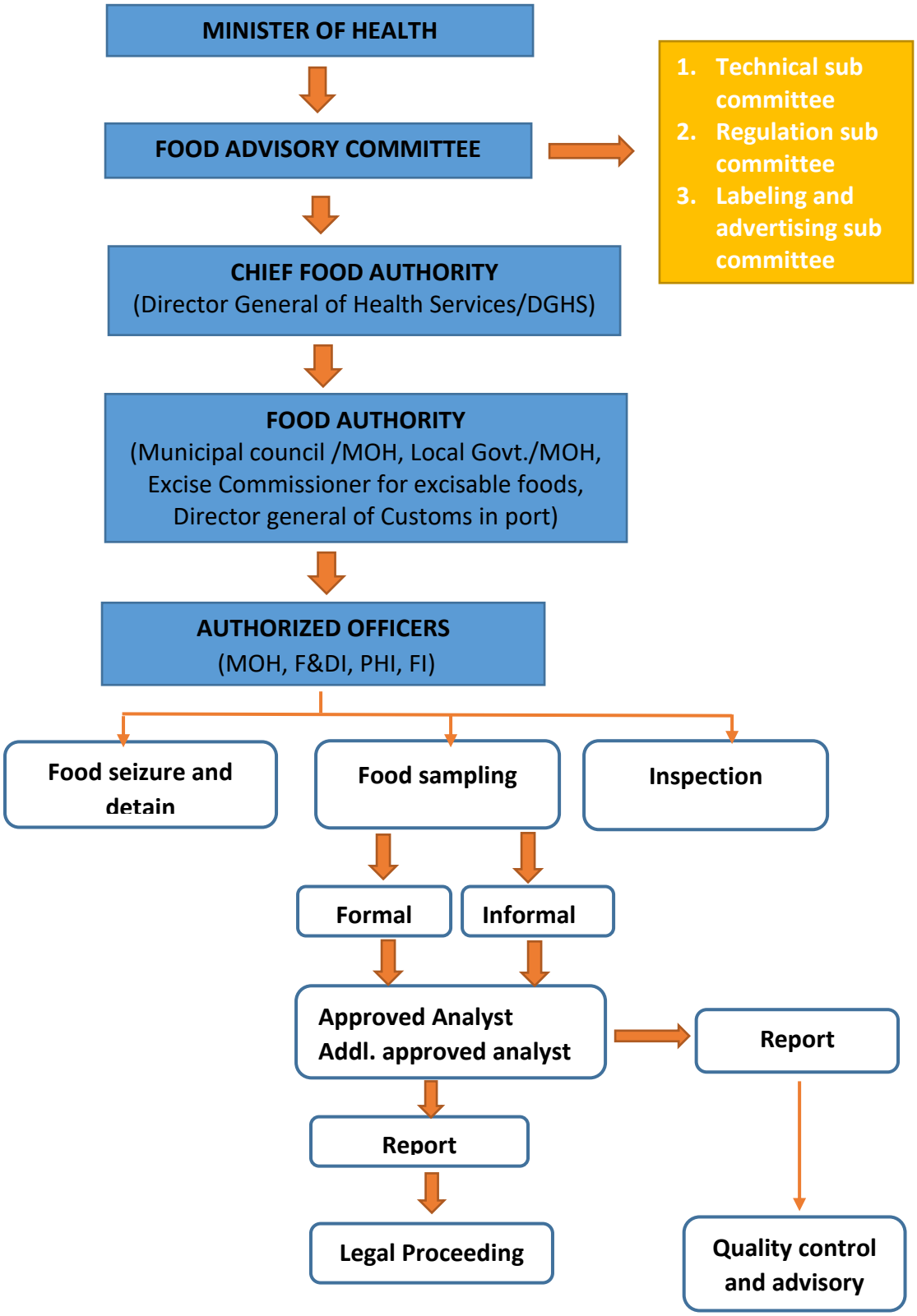
The main law covering food safety is the Food Act No. 26 of 1980. This law is basically implemented through the Director Health Services (DHS) and through local authorities and respective MOH offices in the region.

Different aspects of the food safety are implemented by many departments and institutions. Director General of Health Service (DGHS) is the Chief Food Authority (CFA), functioning as the Chairman Food Advisory Committee (FAC) which advises the Minister on matters arising during administration of the Food Act.

FAC consists of three sub committees as indicated in Figure 4.3. Technical sub-committees are established under the Food Act and consist of members from Health, Environment, Standards body, two experts, nutritionist and the testing laboratories.

Food safety in the Colombo city is controlled by the Colombo Municipal Council (CMC) through the Chief Medical Officer of Health (CMOH) and a team of Food

Inspectors (FI) and Public Health Inspectors (PHI). The Director General of Customs assisted by Food and Drug Inspectors (authorized officers) becomes the food authority for imported products.



Source: HARTI Survey Information adopted from the Ministry of Health

Figure 4.3: Implementation of Food Act No. 26 of 1980 in Sri Lanka

4.8.2 Food Authority in the Country

For administrative areas in the country, a municipality, any other local authority a Medical Officer of Health (MOH), is appointed by the Minister as the food authority for that area. If the local authority constituted for that area is not appointed as the food authority then the Superintendent of Health Services in an area, or Excise Commissioner in the area, or principal collector of custom, shall be authorized for all food related aspects in that area.

4.8.3 Authorized Officers (AO)

- Medical Officer Health (MOH), Food and Drug Inspector
- Public Health Inspector (PHI), Food Inspector
- Veterinary Surgeon for Meat only
- Officer authorized by the Excise Commissioner or Director General Customs

4.8.3.1 Duties of Authorized Officers

1. Inspection of food samples
2. Seize and detain (inform the relevant Food Authority) of food samples
3. Food Sampling – formal or informal
4. When AO is MOH, DG of Customs, Commissioner General of Excise can examine records and make copies
5. No person shall obstruct AO
6. No person shall make misleading or false statements to AO
7. Any seized food may be kept or stored in the same building or removed to any other place at his discretion
8. AO shall inform the relevant Food Authority of any seizure made under the Act
9. Seized articles may be destroyed if Authority is satisfied that there has been contravention of any provisions of the Act/Regulations. The owner should consent in writing to this effect
10. Inform the Magistrate Court and follow up

4.8.4 Approved Analyst

Once collected the food sample will be sent either to the Government analyst or other additional approved analysts in the relevant area for further investigations and they issue reports for quality control and advisory committee or to take up legal proceedings.

• The Government Analyst
• Additional Approved Analysts
- City Analyst, Colombo MC
- City Analyst - Kandy
- Medical Research Institute (MRI)
- NIHS Lab- Kalutara
- Anuradapura Lab
- Kurunegala

CHAPTER FIVE

Lessons and Experiences of Reducing Post-harvest Losses and Maintaining Quality and Safety of Fruits and Vegetables in Asia-Pacific Region

5.1 Introduction

This chapter provides scientific information about post-harvest losses and issues related to food safety and its causes. Alongside, it deals with strategies followed by South Asian and Asia - Pacific countries in reducing post-harvest losses and measures taken in assuring food safety, in fresh fruit and vegetable supply chain.

The Asia-Pacific region accounts for approximately 30 percent of the world's land area. The Asia-Pacific region contributes to more than 50 percent of the world's acreage under fruits and vegetables and produces a range of fruits such as apples, bananas, oranges, grapes and mangoes in addition to tropical and sub-tropical fruits such as pineapples, papayas, guavas, lychee and passion fruit. Asia and the Pacific region have witnessed rapid growth in horticultural development. Changes in dietary habits owing to increasing incomes continue to accelerate demand for horticultural produce in the region. Poor infrastructure for storage, processing and marketing in many countries of the region contributes to a high proportion of waste averaging between 10 and 40 percent. Considerable waste occurs for small scale resourced poor farmers being unable to market their produce and implement suitable post-harvest handling practices. Spoilage of fresh produce is also accelerated by the hot and humid climate of the region (Choudhury, 2006).

According to the Food and Agriculture Organization of the United Nations (FAO), 15-50 percent of agricultural produce is lost between harvesting and marketing in countries in the Asia Pacific region (SATNET Asia, 2014).

High income countries such as Japan, the Republic of China and the Republic of Korea have been successful in implementing post-harvest management systems which minimize losses in perishables, while middle income countries such as the Philippines, Thailand and Malaysia are streamlining systems and strategies to upgrade post-harvest capacities. Many low and middle income countries continue to focus on capacity building to minimize losses in fruits and vegetables as they struggle to overcome technical, infrastructural and managerial constraints while maintaining quality and safety.

Poor infrastructure in terms of storage, processing industries and marketing in many countries of the region contributes to high wastage. Large presence of small and marginal farmers in the production and dominance of small and cottage scale units in the processing have further complicated the scenario because of their poor access to resources, technology and credit. Integrated post-harvest management with

proper infrastructure and timely policy initiatives would stride towards reduction of post-harvest losses of fruits and vegetables (Choudhury et al., 2004).

Fruits and vegetables are subjected to high price and quantity risks with changing consumer demand and production conditions. Unusual production and/or harvesting, weather conditions or major crop diseases can disrupt fruit and vegetable marketing patterns.

Table 5.1: Estimated Levels of Post-harvest Losses in the Asia-Pacific Region

Country	Estimated Level of Losses (%)
India	40
Indonesia	20–50
Iran	>35
Korea	20–50
Philippines	27–42
Sri Lanka	16–41
Thailand	17–35
Vietnam	20–25

Source: Rolle, 2006

The food production, processing and marketing system in Southeast Asia ranges from small-scale to large-scale, with products passing through multiple tiers of handlers and middlemen in the market chain. Facilities and infrastructure are still inadequate, and there is lack of knowledge and expertise on new or modern technologies and practices. Moreover, little appreciation is received for good hygienic practices (GHP), good agricultural practices (GAP), and good manufacturing practices (GMP), especially among smaller-scale food processors.

5.2 Efforts to Reduce Post-harvest Losses in Fresh Fruit and Vegetable Supply Chains: Experience of SAARC Countries

5.2.1 Recently Developed New Technologies in PH Management of Fruits in India

In India, post-harvest loss accounts for 30 percent and in particular, in the horticulture sector the loss is estimated to be 5-39 percent. The total post-harvest loss is worth about US$ 32.7bn annually. Major losses are caused by the lack of adequate food processing units, modern cold storage facilities (lack of capital and power supply) (SATNET Asia, 2014).

1) Pre-harvest Sprays to Reduce Post-harvest Losses

Pre-harvest sprays of chemicals have been applied to reduce post-harvest losses in different fruits. Thiophenate methyl (0.05%) was found to effectively control post-harvest losses in *Dashehari* mango. A pre-harvest spray of 10 to 15 ppm gibberellic acid (GA_3) proved useful for on-tree storage of mango by controlling maturity and

delaying ripening. A pre-harvest spray of 0.6 percent calcium chloride, 10 to 12 days prior to the harvest improved the shelf life of grapes.

An additional 2,720kg/ha mango yield was obtained as a result of the pre-harvest spray of bavistin (0.5%). Spraying of two percent urea on to banana bunches increased bunch weight by 2-5 percent. Pre-harvest heat treatment by reducing the ventilation in green houses increased the soluble solids content, fruit skin colour and reduced the chilling injury of tomatoes. Application of 25 percent of etherel along with two percent urea in addition to 0.04 percent sodium carbonate of solution (50ml) facilitated uniform flowering and fruiting in high density pineapple plantations.

2) Tools Developed for Mechanical Harvesting

Mango Harvester - Cost-effective equipment for the quick and easy harvesting of mango with a pedicel length of 12cm, was designed by the University of Agricultural Sciences in Bangalore. This equipment helps prevent the flow of latex on to the fruit surface and thus prevents tissue damage.

Raw Mango Peeler - Between 25 and 30 percent of unripe mangoes are lost during fruit set and development in orchards due to weather conditions. These unripe mangoes are processed into value added products such as pickles, chutneys and dry powders. In order to facilitate their peeling, the Indian Institute of Horticulture Research in Bangalore has developed an integrated grader/peeler with a capacity of one metric ton/hour.

3) Pre-cooling

Pre-cooling technology is extensively applied in the post-harvest handling of horticultural produce. Pre-cooling of mangoes to 12–15^{0}C with 500 ppm Bavistin has shown to increase their shelf life.

4) Grading

Systematic grading coupled with appropriate packaging and storage extend post-harvest shelf life, wholesomeness, freshness and quality which substantially reduce losses and marketing cost. Horticultural produce are sorted and graded on the basis of parameters such as maturity, size, shape, colour, weight, being free from insects and pests, pesticide residues and ripeness.

5) Packaging and Transportation

Large quantities of mangoes, bananas, oranges and other fruits and vegetables are transported in open trucks. Window type conical bamboo baskets for stacking and aeration have been developed for transportation of produce by rail. The use of polyethylene film bags for wrapping whole bunches of bananas for transport has been found to be most suitable to minimize wastage. The use of wooden crates with

the internal dimension of 42x32x29 cm has also been recommended for the long distance transportation of bananas in India.

6) Storage

Storage life is governed by several factors: variety, stage of maturity, rate of cooling, storage temperature, relative humidity, rate of accumulation of CO_2, pre-packing and air-distribution systems. Optimum refrigerated storage requirements for different fruits are as follows: 1.7–3.0°C for apple, 12.8°C for banana, 0–1.7°C for grapes, 8.3–10°C for guava, 8.3–10°C for mango, 5.5–7.2°C for orange and 8.3–10°C for pineapple.

7) Edible Coatings

Composite coating of polysaccharides (cellulose, pectin, starch, alginate, and chitosan), proteins (casein, soy) and lipids (waxes, mineral oils) have been extensively used in controlling spoilage of fruits and vegetables. Antioxidants such as Butylated Hydroxyanisole (BHA) and Butylated Hydroxytoluene (BHT) are added to protect against oxidative rancidity, degradation and discouloration.

8) Minimal Processing

Minimally processed products are convenient ready-to-use or ready-to-eat fruits and vegetables with fresh-like quality and containing natural ingredients. Fruits such as pomegranates and vegetables such as carrot, beans, cauliflower, cabbage, okra and tomato are cut, diced or shredded to uniform size for commercial markets.

(Source: Kriesemer et al., 2009)

5.2.2 PH Management of Fruits and Vegetables in Bangladesh

Post-harvest loss in Bangladesh represents about 20-40 percent in fruits and about 8-25 percent for vegetables. The main losses occur soon after harvesting during handling and transport. Major causes of post-harvest losses are lack of appropriate knowledge on handling and storage, inadequate sorting and grading, poor washing, inappropriate packaging, transportation problems, rough handling at loading and unloading, lack of packing houses and cold storage facilities and lack of improved PH technologies. In the entire supply chain, maximum losses occur due to poor packaging and inappropriate transportation system (SATNET Asia, 2014).

5.2.3 PH Management of Fruits and Vegetables in Nepal

Major causes of post-harvest in Nepal are due to improper harvesting, poor sorting and grading, lack of sufficient infrastructure, improper storage facilities, lack of appropriate facilities for handling, packaging and transportation. Access to production and post-harvest handling technologies is also poor. In general volumes are low, seed quality is low; so is the produce. About 20-35 percent of fruits, 15-30

percent of vegetables and 15-20 percent of potatoes are lost, mainly at loading, transportation and retail Level (SATNET Asia, 2014).

Agriculture Research and Development Centres of Nepal, local non-government organizations (NGOs), international NGOs and extension agents, currently devote considerable attention to the development and dissemination of post-harvest technologies for fruits and vegetables in Nepal. Major areas targeted for the reduction of post-harvest losses in fresh vegetables include harvesting at the appropriate stages of maturity, harvesting methodologies, trimming, grading, packaging and storage.

1) Harvesting

Harvesting techniques and maturity indices for apple, orange and banana have been established. Harvesting bags and knives have been developed and distributed to individual farmers on a 25 percent subsidy. Hand harvesting is also undertaken in specific situations.

2) Grading and Sorting

Grading equipment has also been designed and developed on the basis of these grades and is being distributed to collection centres and farmers' groups with a 25 percent subsidy.

3) Packaging

Improvements in the traditionally used packaging such as *doko, tokari* and *bhanga* have been recommended. These improvements provide for cushioning or lining with rice straw, pine leaves, banana leaves and paper at the base and sides to protect from roughness of the packaging.

Doko - This is a bamboo made basket used to carry fruits and vegetables on the back, in the hills. It is conical in shape with a slightly narrowed base. It generally has a capacity of 40–50kg.
Tokari - This is a bamboo basket having a capacity of approximately 40kg and is used to carry fruits and vegetables on the head.
Bhanga - This is flat basket made of bamboo, to which tokari and jute materials are attached at the top to accommodate a larger volume of produce. It is used in the plains for the packaging of vegetables. It has a capacity of between 100 and 150 kg.

Improved packages include crates, cartons, wooden boxes and polyvinyl bags. Crates are usually plastic crates which have a capacity 20–25kg. Plastic crates have been found to be the most satisfactory form of packaging for the transportation of fresh vegetables such as tomatoes, cucumbers, capsicum, and gourds (e.g., sponge gourds, bitter gourds). Crates having a capacity of 20kg are used for mandarin oranges.

Cartons - These have a capacity of 20kg and are used for fruits like apples and mandarin oranges depending upon the compression and bursting effect. Wooden boxes being rather costly, these are not generally recommended. Improved traditional packaging has proven to be more convenient during transportation and less damaging.

4) Storage

Rustic stores:
These are structures having dimensions of 195cm length x 75cm width x 225cm height, which contain five racks with the capacity for the storage of 500kg of potatoes. These stores are fenced by mesh wire to keep out pests and animals. They are covered with straw and grasses. Apples and potatoes can be stored in these structures.

Zero-energy storage structure:
Fresh vegetables and fruits are stored in zero-energy storage structures. These are constructed using local materials such as brick and sand. The structure is double walled with a 4" (10cm) space between two walls which enclose a central storage space having dimensions of 75cm x 50cm x 75cm. Sand is kept moist by sprinkling water regularly to maintain a temperature of 7 to 10^0C. It is covered by a jute matrix which is also kept moist.

Cellar store:
The cellar store is a warehouse constructed from locally available construction materials such as stone, mud and sand. The temperature within a cellar is maintained between 4–9^0C, while the humidity is maintained between 75 and 90 percent. Cellars are used for the storage of apples, mandarins, oranges and sweet oranges.

Regarding sweet oranges and apples, a relative humidity range of 90 to 95 percent and temperature range of 8^0–12^0C temperature are maintained in improved cellar stores to achieve a storage shelf life of 100–120 days. Improved cellar storage has been found appropriate for those two types of fruits. Furthermore, farmers in the remote hills have utilized improved cellar stores for potatoes, cabbages and taro. Currently, improved cellar storage is being disseminated to various stakeholders by extension agents (Adhikari, 2006).

5.2.4 PH Management of Fruits and Vegetables in Vietnam

Main packaging material differs with each chain actor; bamboo basket for collectors, Styrofoam box for wholesalers and plastic bag for retailers. Other more frequently used packaging materials are Styrofoam and wooden box for collectors and bamboo basket for wholesalers.

Some examples of methods that have been used to improve quality include:

- Treatment of citrus with ethylene (ethrel) to remove the green colour (de-greening)
- Packing oranges and grapefruits in orange mesh bags to reinforce the colour of the fruit
- Minimizing water loss. Water loss can be minimized in citrus fruit by packaging, waxing or low temperature storage. Rapid pre-cooling of fruit such as longan and rambutan also reduces water loss. Minimizing physical damage to fresh produce can also reduce water loss.
- Determination of commercial maturity.
- Minimize the period over which the fruits and vegetables are marketed
- Low temperature storage (8–12^{0}C) depending on the type of fruit or vegetable

(Source: Hai and Yen, 2006)

5.2.5 PH Management of Fruits and Vegetables in Thailand

Packing

Fresh produce is generally packed in plastic crates, plastic bags or corrugated paper boxes in Thailand. Corrugated paper boxes are used for the packaging of uniformly sized produce such as avocadoes, mangoes and oranges. Boxes protect the commodity by cushioning and immobilizing it. They are easily handled throughout distribution and marketing and can minimize the impact of rough handling. Boxes serve as a moisture barrier and designed with appropriate ventilation capacity.

Polyethylene can be easily sealed, has good O_2 and CO_2 permeability, low temp durability and good tear resistance and is of a good appearance. This film is therefore used for the production of Modified Atmosphere Packaging (MAP) which can be manipulated to match the characteristic respiration of produce by reducing O_2 levels to slow down the respiration rate, metabolic rate and senescence of the produce.

Transportation

Modified atmosphere (MA) packaging and controlled atmosphere (CA) packaging are used for different fruits and vegetables. MAP creates a steady atmosphere of O_2 and CO_2 around the produce within the MAP package, while CA provides an optimum atmosphere of oxygen and carbon dioxide around the packaged produce. MAP has been developed to match specific produce requirements and can be combined with CA storage. Temperatures are maintained at an optimal level during transportation.

Advantages of MAP Packaged Produce in CA Storage

- Quality of internal and external colour and flesh maintained
- Reduced chilling injury
- Delayed ripening and senescence
- Texture of fruit maintained

- Shelf life of fruit increased and the frequency of delivery reduced
- Reduced decay and weight loss

(Source: Sirivatanapa, 2006)

Minimally processed fruits and vegetables are gaining popularity in Thailand. Minimal processing involves cleaning, peeling, cutting, slicing, packaging or processing by any means short of denaturing the fruit or vegetable tissues. Durian, jakfruit, mangosteen, papaya, pineapple, pummelo and young coconut are often marketed in the minimally processed form in Thailand. Major reasons for the minimal processing of these fruit include:

- Large fruit size. Several tropical fruits are bulky. A single fruit may weigh more than 10kg. Thus minimal processing allows the fruit to be conveniently packaged in quantities appropriate to consumer needs.
- Risk of obtaining poor quality pulp. Pulp quality varies greatly. Thus minimal processing allows high quality pulp to be marketed.
- Difficulty in peeling. Durian has numerous sharp spines that are dangerous to consumers, if not skilled in opening the fruit. Jakfruit contains gummy exudates that can stain clothing and adhere to the hands.

(Source: Techawongstien, 2006)

5.2.5.1 Post-harvest Technologies for Leafy Vegetables

(1) Controlling water loss

To reduce water loss, the produce is kept under cool temperature and high relative humidity. The produce is packed in perforated plastic bag or individual film wrap, such as polyvinyl chloride (PVC) film. The type of film depends on the kind of leafy vegetable. Air movement through produce is essential to remove the heat of respiration, but the rate of air movement must be kept as low as possible to avoid excessive water loss. At ambient temperature condition, leafy vegetables are kept under high humidity. In supermarkets, cabbage and Chinese cabbage are packed in perforated plastic bags (with 4 to 8 holes with 5 mm diameter) or individual wrap with PVC film at shelf temperature of 7^{o}C.

For Chinese kale, perforated plastic bags (with 4 to 8 holes) or polyethylene (PE) bags with one open end are used. In addition, hydro cooling Chinese kale by dipping in 4^{o}C water for 5-10 minutes prior to 7^{o}C storage was found to control water loss and extend shelf life.

(2) Controlling high temperature injury

After harvest, the produce are kept in the shade or protected from exposure to sunlight. For Chinese kale, removal of field heat can be performed by pre-cooling as mentioned above. The produce has been found to show the freshness quality

desired by supermarkets. However, if the produce is to be sold in traditional markets, water spray is enough to reduce field heat. For cabbage and Chinese cabbage, trimming of outer leaves is done before keeping in the cold room (7-10^{o}C).

(3) Controlling chilling injury

Chilling temperature damages the cell and tissue of susceptible leafy vegetables. Thus, chill-sensitive produce are not kept at too low temperature. Leafy vegetables can be kept at 7^{0}C, similar to the temperature of refrigerated shelves in supermarkets. This is particularly true for Chinese cabbage and Chinese kale. If Chinese kale is kept at quite high temperature, leaf yellowing rapidly develops. For common cabbage, temperatures lower than 7^{o}C can be used.

(4) Controlling yellowing

Yellowing in leafy vegetables is undesirable. Leaf yellowing may be related to genetics (i.e. cultivars), exposure to abusive temperatures, exposure to exogenous ethylene, and the level of stress tolerance inherent in the leaf tissue. Five possible strategies which are used to reduce yellowing;

1) breeding for improved resistance to yellowing
2) improved handling and transport system that provide good temperature control
3) segregation from or control of exogenous ethylene
4) increased tolerance to abusive temperatures
5) control of ethylene response

Pre-cooling (hydro-cooling at 4^{o}C for 5-10 minutes) has been shown to minimize the problem. Also, maintaining of temperature during handling, transport and distribution has reduced leaf yellowing. In addition, produce should be protected from exposure to ethylene. This is done by separating leafy vegetables from high ethylene-producing products, such as ripening climacteric fruits.

(Source: Kanlayanarat, 2007)

5.2.6 PH Management of Fruits and Vegetables in China

5.2.6.1 Reducing Post-harvest Losses in Traditional Marketing Systems in China

(1) Ice Packaging

Ice packaging is used for cooling vegetables during their distribution through the traditional marketing system. Ice packaging is also effective in reducing leaf yellowing, wilting and trim loss. In the case of vegetables such as edible amaranth and long yard bean, which are susceptible to chilling injury, a layer of newspaper is placed between the layers of vegetables and ice. The thickness of the alternating layers of vegetables and ice is dependent on the type of vegetable, the ambient temperature and the distance or the time to the market.

(2) Hydro-cooling

Hydro-cooling by dipping in cold water is extensively used for long yard beans and bamboo shoots. Leafy vegetables and long yard beans are repeatedly sprayed with water in shipping point markets, in order to maintain low temperature and to prevent wilting or softening, particularly during the summer months.

5.2.6.2 Reducing Post-harvest Losses in Modern Marketing Systems in China

In the modern marketing system, cleaning, sorting, repacking and pre-cooling treatments, generally take a day. Maintaining low temperatures throughout this process is essential to reduce post-harvest losses. Vegetables are cooled upon arrival at packing stations. The packed produce is maintained at low temperatures during transportation, short term storage and retailing. Cold chain systems were developed to meet the requirements of supermarkets. The cost of maintaining a cold chain system is, however, very high, given the high cost of the equipment and its operation.

1) Pre-cooling techniques adopted in the Republic of China

Hydro-cooling
Hydro-cooling is commonly applied for the rapid removal of field heat from fruits and vegetables and many kinds of leafy vegetables. Hydro-cooling increases the freshness of leafy vegetables. Hydro-cooled vegetables are kept cool in order to prolong their shelf life.

Room-cooling
Room cooling is a simple pre-cooling technique. Vegetables are simply retained in a refrigerated room prior and subsequent to packaging. Room cooling takes longer than other cooling methods. It is used for cooling vegetables such as cabbage and head lettuce, that cannot be cooled by either hydro-cooling or forced air cooling. Room cooling can also be applied in the cooling of fruity vegetables and is widely used for the cooling of vegetables packed in consumer packages.

Forced Air Cooling
Forced air cooling is widely applied in cooling vegetables destined for delivery to institutions such as supermarkets, for storage and for long term transportation such as oversea transportation. It cools the produce at a more rapid rate than room cooling does, and thus increases efficiency in the cold chain. Forced air cooling is therefore, important in modern marketing systems. The facilities and techniques for forced air cooling have been developed and adapted by small companies or cooperatives in the Republic of China. Tunnel stacking, forced air cooling system is the most popularly used pre-cooling systems in the Republic of China. High refrigeration capacity and high relative humidity are extremely important in forced air cooling systems. Cooling efficiency is affected by the method of packing and the quantities and types of vegetables to be cooled. In some cases, forced air cooling is

substituted with vacuum cooling owing to the higher efficiency and lower labour requirements of the latter. Forced air cooling facilities are, however, much less costly than are vacuum cooling facilities.

Vacuum Cooling

Vacuum cooling are commercially used. Almost all types of leafy vegetables can be thoroughly cooled by vacuum cooling within a short period of time. Vacuum cooling is extremely useful for head vegetables such as cabbage and head lettuce. High cost limits the use of vacuum cooling. Currently, only a few cooperatives use vacuum cooling.

2) Packing house operations

At the pack house, good quality produce is selected and defective vegetables are discarded. Leafy vegetables are usually trimmed using a special knife. Damaged and senescent leaves are removed; for some vegetables (e.g. cabbage, Chinese cabbage), the butt is trimmed. The cleaned produce is then sorted based on the buyers' requirements or based on the national industry standards such as that for Chinese cabbage. The cleaned produce is wrapped or bundled before packaging.

3) Packaging and transport

Some vegetables are directly packed into containers. Different types of containers are used for leafy vegetables, depending on the market and value of the produce. For export and high-value leafy vegetables, more rigid and presentable but expensive containers are used such as foam boxes and cartons. For the local markets, bamboo baskets of different sizes and shapes are used. Some produce is packed in plastic crates or handled loosely (no container) when brought to the market. Cooling during transport may be performed by using wet pads as liners or with ice bottles placed together with the produce inside the container. Other techniques in packaging and transport of leafy vegetables include the following:

1. Use of sack liners and cotton-cloth pads and plastic film covers on bamboo baskets
2. Use of paper, stretchable foam cap or plastic film to wrap cabbages individually or in groups of three such as those for Chinese cabbage
3. Use of plastic film liner in cartons
4. Use of foam box with and without newsprint liners
5. Circular arrangement of leaves to protect from damage and water loss
6. Use of refrigerated truck with temperatures of 1-4^{o}C

4) Storage

Simple refrigerated storage facilities have been developed for the storage of fresh produce including leafy vegetables. Most leafy vegetables are stored at 1-2^{0}C and relative humidity of 90- 95 percent. Mixed storage with fresh fruits such as apple, pear, and peach is avoided as these fruit produce high levels of ethylene, which

promotes yellowing and senescence of the leafy vegetables. Vegetables to be sold in the local market (wholesale or retail market) are often harvested in the early morning or after sunset and the harvested produce is covered with wet pads or plastic film for cooling and preventing excessive water loss. For vegetables to be shipped to distant or export markets, the harvested produce is brought to a packinghouse where different operations are carried out, including cold storage, before being transported.

(Source: Huang, 2006)

5.2.7 PH Management of Fruits and Vegetables in Malaysia

Proper packing house operations are conducted by Federal Agriculture Marketing Authority (FAMA) at modern packing house complexes located throughout the country.

The use of returnable plastic containers has been well adopted by FAMA for transportation in local markets and to Singapore. Local traders still, however, show a preference for traditional packaging methods such as the use of bamboo baskets owing to their low cost and ease of disposal.

For the local market, induced ripening is normally carried out to overcome the uneven ripening of certain types of produce. Calcium carbide is the most commonly used ripening agent in Malaysia. Controlled ripening rooms and ethylene gas are applied to fresh produce for export. Ripening rooms and ethylene gas have been used by FAMA over the past few years (Muda, 2006).

5.2.8 PH Management of Fruits and Vegetables in Philippines

Approaches and Technologies to Reduce Post-harvest Losses in Fruits

Reduction of post-harvest losses in perishable commodities necessitates an integrated approach to production, post-harvest handling and marketing. Such an approach is embodied in a Quality Assurance Programme (QAP) for each commodity, designed to meet consumer requirements of consistent quality and volume. QAP is a management system for controlling quality by establishing operational procedures involving the integration of procedures in production and post-production, services and people concerned with the product. So far in Philippines, QAPs for banana (Cavendish and Bungulan varieties), pineapple (Smooth Cayenne variety) and papaya (Solo variety) have been established and implemented by multinational companies involved in the production and export marketing of these commodities.

The Post-harvest System Improvement (PSI) is an approach for identifying post-harvest problems, assessing the levels of losses and applying post-harvest interventions to reduce or minimize losses in perishable crops. PSI employs the use of several methodologies to effectively attain the overall objective of reducing handling- related losses and maintaining fresh produce quality. These methodologies

include: handling trials, quality profiling, establishment of packing houses that guarantee control and consistency of product quality and sustained volume, prior to marketing consolidated volumes of produce and establishment and implementation of quality standards. Improved post-harvest handling systems (IPHS) for Saba bananas, Solo papayas, Carabao mangoes, Queen pineapples and calamansi have been established in cooperation with producers and the private sector.

The development of science-based post-harvest technologies has been delegated to academic institutions in the Philippines whose mandate is to conduct research and development in the area of post-harvest in the country so far. Notable technologies generated by these research and development institutions and that have had a significant impact in reducing post-harvest losses in fruit crops in the Philippines are the following:

(1) Optimized hot water treatment protocols for the control of anthracnose and stem-end rot diseases in mangoes and papayas and for alleviating chilling disorders in Queen pineapples
(2) Controlled atmosphere protocols (CA) to delayed ripening of Carabao mangoes for export
(3) Modified atmosphere (MA) packaging/storage protocols for delayed ripening and deterioration of papaya and calamansi;
(4) Waxing with fruit coatings synthesized and formulated from coconut oil for delayed ripening and to minimize the development of physiological disorders in pineapples and papayas;
(5) Cold chain systems at major trans-shipment routes
(6) Optimized quarantine protocols (vapour heat treatment and irradiation) for disinfestation against fruit flies without prejudice to the quality of fresh mangoes and papayas for export to Japan, the US, Australia and Korea

5.2.9 PH Management of Fruits and Vegetables in Singapore

Post-harvest losses in fresh fruits and vegetables average around 10-20 percent in Singapore depending on the type of fruit or vegetable. Vegetables are generally harvested in the late afternoon, although in some cases, they are harvested in the morning. Leafy vegetables are cut manually at the stem from the growing beds, following which they are trimmed and packed directly into plastic crates lined with newspaper. This produce is temporarily placed under shade provided by a beach umbrella in the field to reduce evaporation from the cut stem. Further, to avoid accumulation of heat due to the hot weather in Singapore, farmers are advised to transport the vegetables to a proper shed or pre-cooling room within half an hour of harvesting.

Vegetables after being harvested sold in bulk are cut, sorted, trimmed and packed in plastic crates in the field. These operations are carried out under a beach umbrella to avoid direct sunlight and to reduce moisture loss. In addition, cold rooms are used on few farms for vegetable storage, prior to delivery. The harvested vegetables are packed in PVC crates, pre-cooled for either a few hours or overnight in a cold room

maintained at 3–5^{0}C, prior to processing and packaging. Vegetables are packaged in units of either 200g or 400g and packaging is carried out in a packing house maintained at 18–20^{0}C.

Generally, vegetable imports from Malaysia are either packed in bamboo baskets, paper boxes or PVC crates and are transported by truck under ambient conditions to the Singapore Vegetable Wholesale Centre. However, leafy vegetables imported from Indonesia are packaged for retail sale and are transported via a cold chain.

(1) Vegetables are pre-cooled for a few hours to remove field heat prior to retail packaging. The retail packaged vegetables are transferred to paper boxes and stored in cold rooms either for a few hours or overnight
(2) The boxes of vegetables are transferred from cold storage via a refrigerated truck to a refrigerated boat for shipment to Singapore to minimize PH losses
(3) Almost all of the fruit and vegetable import from China, Thailand, Australia and Vietnam are transported in refrigerated containers (40 ft) via a cold chain. Fruits, vegetables and high value leafy vegetables are packed in Poly-styrofoam boxes after pre-cooling
(4) High value imported perishable fruits such as strawberries are generally transported via a cold chain system to extend their shelf life

5.3 Efforts to Manage Food Safety Related Issues in Fresh Fruit and Vegetable Supply Chain: Experience of SAARC and other Asia-Pacific Countries

National food safety programmes in this region generally lack the following critical elements: identifying of the nature and extent of national food safety problems, awareness of the consequences of contaminated food on the nation's health status and economic development and urgency for the need to investigate and conduct research. Specific food safety policies are either non-existent, inadequate or of low priority in most of these countries (Othman, 2007).

Challenges

1. Legislation

Establishing and updating food legislation is the first step in establishing an effective food safety system. National regulatory standards must be formulated and reviewed based on risk assessment and thus incorporate available scientific evidence. Whenever possible, these standards must be harmonized with international standards, i.e., the Codex standards.

2. Food Control Management

This approach consists of risk assessment, risk management and risk communication and provides a framework for governments to effectively assess, manage and communicate food safety risks among all relevant stakeholders.

3. Food Inspection

Competent food inspectors who are adequately trained and equipped for food inspection are vital in ensuring consistent, transparent and effective food inspection.

4. Food Control Laboratory

Adequate laboratory infrastructure is required to support the monitoring, surveillance and enforcement activities. These include adequately equipped food control laboratories, trained analysts and the implementation of the Quality Assurance System that meets international standards.

5. Information, Education, Communication and Training

Sharing information, education and advice among stakeholders across the farm-to-table continuum is essential to enable food safety programmes to reduce the incidence of food-borne disease. To achieve this strategy, awareness campaigns on food safety and education materials for consumers and the food industry are needed.

6. Compliance by the Food Industry

Exporters in the food industry need to comply with the importing countries and buyers' requirements. This challenge is significant because different importing countries have different standards and regulatory approaches.

7. International and Regional Trade Frameworks

Keeping up with the development of international standards and guidelines such as Codex poses an enormous challenge to Southeast Asian countries.

Table 5.2: Laws and Regulations Practised in the SAARC Countries to Prohibit Artificial Fruit Ripening and Food Adulteration

Country	Laws and Regulations	Aims and Actions
Bangladesh	Bangladesh Pure Food Ordinance (Amendment) Act 2005	Formation of National Food Safety Advisory Council (NFSAC); prohibit using calcium carbide, formalin, and pesticides in foods
	Agricultural Products Market Act, 1950 (revised in 1985) and the Bangladesh Standards and Testing Institution Act 1985,	To empower Bangladesh Standards and Testing Institution (BSTI) surveillance teams for field test and monitoring
	The Plant Quarantine Act 2011	To prevent unapproved import and export of plants
	The Mobil Court Act 2009	To empower the magistrates of mobile courts
	Bangladesh Consumer Protection Act 2009	To prohibit using any substance in food harmful for human health
	Formalin Control Act 2014	To control the use of Formalin
	The penal code of Bangladesh	To penalize any individual selling illegally ripened fruits
India	Prevention of Food Adulteration Rules 1955	To prohibit the use of carbide gas for fruit ripening
	Food Safety and Standards Act 2006	
	Food Safety and Standards Regulations 2011	Prohibiting the sale of artificially ripened fruits using carbide gas
Pakistan	West Pakistan Pure Food Ordinance, 1960	To address and limit food adulteration
	Cantonment Pure Foods Act 1966	To address and limit food adulteration at the Cantonment areas
Nepal	The Nepal Food Regulation 2007	To prohibit the use of carbide gas for fruit ripening
Sri Lanka	Food Act No 26 of 1980	To prohibit manufacturing, selling, and distributing of any adulterated food
	Food Regulation 1993	To prohibit use of carbide for fruit ripening

Source: South Asian Regional Standards Organization (SARSO); cited in Islam et al., 2016

Headquarters in Dhaka, Bangladesh, South Asian Regional Standards Organization (SARSO) is responsible for harmonizing national standards of SAARC (South Asian Association for Regional Cooperation) member states and for developing SAARC standards on common products of interest. To date, the organization has identified 28 common products for harmonization of standards; however, fruit and fruit-related products are not on the list. SARSO can be used as a platform for issuing a single list of artificial fruit ripening agents that should be banned in the whole South Asia region.

5.3.1 Legal Framework of Indian Government relating to Food Safety Management

The Food Safety and Standards Authority of India (FSSAI) is responsible for active enforcement of the national laws and regulations that govern the retail supply chain and its food processors. SGS in India has FSSAI approved laboratories at Ahmedabad, Cochin, Indore, Chennai, Kolkata, Bangalore, Gandhidham and Gurgaon for testing Agri-food products. A testing programme from SGS can verify the presence of these substances and help ensure the quality and safety of products.

Food safety regulations have been implemented by various Ministries and/or Departments within India. These regulations serve two main purposes:

1) regulation of specifications for foods
2) regulation of hygienic conditions of processing and/or manufacturing

As mentioned in the following, some of these food safety regulations are mandatory while others are voluntary

a) The Prevention of Food Adulteration Act (PFA) implemented by the Ministry of Health – India, outlines specifications for various food products and is mandatory
b) The Agriculture Produce (Grading and Marking) Act implemented by the Ministry of Rural Development - India is voluntary. This particular act set forth the specifications for various agricultural commodities including some processed foods.
c) The Bureau of Indian Standards (BIS) is the largest body responsible for the creation of standards for various food products. BIS standards are voluntary.
d) A number of quality control orders have been issued under the essential Commodities Act. These include the Food Product Order (FPO), Milk and Milk Products Order (MMPO), Meat Product Order and Vegetable Oils Control Order. These orders are mandatory and mainly meant for regulating hygienic conditions.

(Source: Ashan, 2004)

5.3.2 Food Safety Assurance Strategies in Singapore

This high level of food safety is due to the vigilance of the Agri-food and Veterinary Authority of Singapore (AVA). Singapore adheres to the food safety standards set by the Codex Alimentarius Commission. The country adheres to the legally permitted levels of maximum residue limits (MRLs) in its regulation of pesticide levels, microbiological standards (counts), maximum limits of heavy metals (Arsenic, Lead

and Copper) and maximum limits of chemical preservatives such as Sulphur dioxide recommended by Codex for use in or on fruits and vegetables. All of these are stated in the Food Regulations of Singapore. These limits take into consideration the levels of contaminants in fruits and vegetables that can be consumed daily over lifetime without appreciable health risk to the consumer. These limits also have built in safety factor to account for differences in sensitivity. The AVA has also put in place an effective integrated food safety system to ensure that both locally produced and imported fruits and vegetables are safe at source. It has also implemented food safety assurance schemes and programmes.

5.3.2.1 The System of Integrated Food Safety Systems in Singapore

An integrated food safety system, integrates careful food sourcing, the tagging of consignments of produce to trace sources, inspection, laboratory testing, surveillance of high-risk produce based on history of violation of safety standards and industry regulations that help tighten the food safety net. The AVA has imposed very stringent rules and conditions on the import and trans-shipment of fresh fruits and vegetables. To deter illegal and non-conforming imports, random surprise checks are carried out at checkpoints and lorries carrying fresh fruits and vegetables by road are required to call at the Singapore Vegetable Wholesale Centre for 100 percent checks. Fruit and vegetable imports into Singapore must comply with safety requirements as stated in the Control of Plants Act. For instance, importers are required to submit a phytosanitary certificate with additional certification on freedom of regulated pests. They must also pass a post-entry inspection at premises pre-approved by the AVA. A three-month suspension of the imports of specific vegetables and fruits will be imposed on importers whose produce repeatedly fail laboratory tests. In addition, any person without a license and permit is prohibited from importing and trans-shipping fresh fruits and vegetables. Any person who contravenes the regulatory requirement under the Act shall be guilty of the offence.

5.3.2.2 The Food Safety Assurance Schemes of Singapore

The Good Agricultural Practice Certification Scheme was introduced to vegetable farmers by the AVA. This scheme which was developed to align Singapore with international guidelines seeks to establish a national benchmark for the production of safe and good quality local vegetables by promoting a safety assurance system at source. It also inculcates a sense of responsibility amongst local vegetable farmers for ensuring the production of safe vegetables of good quality for consumers in Singapore. This scheme also provides a product differentiation mechanism for local consumers who wish to purchase GAP certified vegetables. Thus the scheme benefits the farmers mainly in marketing their produce, retailers in meeting increasing consumer demand for safe vegetables and consumers in enjoying the quality and safe vegetables.

5.3.2.3 Food Safety Awareness Programmes of Singapore

- A number of food safety awareness programmes exist in Singapore.

- Food safety campaigns designed to educate the public are also held in Singapore.
- The AVA also promotes food safety by grading the fruit and vegetable service industry.
- The food factory grading system categorizes food factories into either of four grades: A, B, C and D. This grading system is based on their food hygiene and food safety standards. Its objective is to raise the food manufacturers' awareness on hygiene and food safety standards and the need for improvement. It helps create higher standards among food manufacturers and the desire to improve by striving to obtain higher grades. The AVA also rewards farmers and importers under the Food Safety Partnership Award Scheme to spur the food industry to achieve higher food safety standards in their operations and to adopt a more pro-active approach to consumer education on food safety.

5.3.3 Safety Inspection Systems of Agricultural Produce in Korea

Safety inspection is conducted for residues of harmful substances such as pesticides and heavy metals in agricultural produce; which is grown, produced, stored and shipped. In situations where produce is determined to be unsafe, measures are taken by the National Agricultural Quality Management Service (NAQS) to either delay or cancel shipments or to implement prosecuting producers to prevent the distribution of unsafe produce.

Measures to Improve Safety Management of Agricultural Produce

- Develop infrastructure for safe production
- Enforce an education system which promotes safety
- Increase environment-friendly, low input agriculture
- Increase safety-related research and development
- Widespread introduction of GAP

- Reinforce monitoring
- Develop monitoring infrastructure
- Extend the scope of safety inspection
- Extend listed pesticides and standards for pesticide residue limits
- Extend the participation of local government

- Reinforce labeling
- Reinforcement of the control of illegally circulated agricultural products
- Reinforcement of public awareness
- Introduction of traceability systems
- Integration of several labeling and certification systems

- Increase consumer participation
- Enforce education and target publicity toward consumers
- Extend consumer participation
- Build safety portals for agricultural produce and food
- Organize advisory committees for the safety of agricultural produce and food

5.3.4 Agriculture Products and Foodstuff Quality and Safety Assurance System in China

In China, the overall food safety is governed by the 'Food Safety Law of the People's Republic of China.' This law covers the standards, inspection, supervision and administration and legal liabilities concerning food safety. According to this law, production or distribution of food or food additives containing contaminants and heavy metals above the safety standard limit is punishable by a fine or revoking of license depending on the extent of the offense. Additionally, 'Food Hygiene Law of the People's Republic of China,' 'Regulation on Managing Hygiene in Food Additives' and 'Law on Agricultural Product Quality' aim to prevent food contamination and use of food additives that are harmful to human health (Yang, 2011; cited in Islam et al., 2016).

In 2015, the Standing Committee of China's National People's Congress revised the 2009 Food Safety Law of the People's Republic of China (Food Safety Law). The revisions to the Food Safety Law are wide-ranging, imposing stricter controls and supervision on food production and management. The new Food Safety Law is significant for China as its amendments and revisions will improve the quality of food products and public confidence in the Chinese food industry. Many of the provisions serve to clarify, consolidate and expand pre-existing food safety restrictions under specific regulations for the relevant product categories, but with more severe penalties. The new law also gears regulatory bodies with more authority, sets harsher penalties for violations and introduces more guidelines for consumer product manufacturing and production.

5.3.5 Food Safety Assurance Efforts of Bangladesh Government

In the National Food Policy Plan of Action (NFPPA) 2008-2015, food safety and quality issues have been given due importance. The main safety related concerns are adulteration and contamination by heavy metals, microorganisms, toxins and chemical residues. All stakeholders in supply chain including supply side (producers, transporters, processors and merchants); government inspection and regulatory authorities, support institutions (labs, training centres, etc.) and consumers have responsibilities to ensure safety of food products and protect consumers' health. In addition to traditional GAP, control operations relying on hazard analysis and risk prevention are to be made mandatory, especially in the case of large scale production and processing facilities (Hassan, 2014).

Presently, there are about 17 laws in Bangladesh to regulate safe food delivery to the consumers. It will require a substantive reduction in crop losses in both the pre- and post-harvest elements of the vegetable market chain.

The Ministry of Health and Family Welfare has set up a Food Safety Unit within the Institute of Public Health of the Directorate General of Health Services (DGHS). For strong coordination of the activities related to food safety and a visible impact, this Unit is supported to develop technical and managerial capacity to tackle food safety

issues. Within the Ministry of Health and Family Welfare, an institutional structure headlined by a high level Food Safety Working Group has been set up. Focal points have been established within the DGHS and the Ministry to co-ordinate on food safety issues. Technical assistance has been provided to develop strategies and actions for prevention and control of food adulteration and contamination. A Food Safety Documentation Centre has been set up in the National Health Library.

5.3.6 Food Safety Assurance Efforts of Japan Government

Since the end of the Pacific War, the Food Sanitation Law and the Japanese Agricultural Standard (JAS) Law have controlled the safety and quality of food for many years in Japan. In addition to the public food safety standards, Japanese supermarket chains set their own company specific quality standards. The number of retailers with their own standards has been increasing recently.

At the time of importation, the most important regulations are those set in the Plant Protection Law and in the Food Sanitation Law. The Plant Protection Law deals with plant quarantine and is applicable to fruits and vegetables only. Food sanitation inspections are applicable to fruits and vegetables and fishery products, and they apply at the time of sale. All food products distributed and marketed in Japan are subject to the labeling regulations. The main law concerning labeling is the “JAS” Law, which explains the details of mandatory and voluntary labeling. Under the plant protection law, fruits and vegetables need to have a phytosanitary certificate issued by the exporting country. Nonetheless, if quarantine pests are found during the import inspection in Japan, the fruits and vegetables have to be treated (disinfected) or discarded depending on the particular conditions.

Under the Sanitation Law, Japan is adopting a system featuring a “positive list” with MRLs for specific pesticides. If the residue exceeds the maximum limit, the product cannot be imported into Japan. If a product contains a pesticide for which there is no specified MRL, the product cannot be imported into Japan. Both food sanitation and quarantine inspections are conducted on each shipment entering the country. However, if the exporting country conducts food sanitation inspections and the government of the exporting country certifies the safety of the products, food sanitation inspection (in Japan) may require only document inspections. In addition to the food sanitation inspections at the port of entry, the Japanese government conducts two other types of food sanitation inspections: inspections at wholesale markets (controlled by the health stations of prefectural governments) and inspections on the sales floors of retailers (controlled by the health centres of prefectural governments) (Jonker et al., 2004).

5.3.7 Food Safety Assurance Efforts of Thailand Government

Strategies for the food safety control system are categorized into five areas based on the concept of risk analysis, which is a pro-active and appropriate approach used to control food safety across the entire food chain. In addition, controlling procedures of the quality assurance system are based on the Hazard Critical Control Point

(HACCP) and Good Manufacturing Practice (GMP) principles. Five strategies of the National Food Safety Programme have been implemented in Thailand as follows:

1. Development of regulatory measures to comply with international food standards
2. Strengthening of food safety monitoring and risk management systems
3. Empowerment of consumers
4. Capacity building and information networking
5. Development of laboratory capability

(Source: Srithamma et al., 2005)

The Responsibilities of Ministry of Agriculture and Cooperatives in Thailand under Road Map of Food Safety

I. Control the agricultural imports, control the import of raw material for food product on (e g. meat, tuna, shrimp)
II. Promote farm GAP mplementation and certification
III. Control of food manufacturing for export
IV. Control of produce/products for export
V. SPS/Trade/International standards setting and negotiation

CHAPTER SIX

Findings, Conclusion and Recommendations

6.1 Introduction

Potential for cultivating fruits and vegetables in Sri Lanka for domestic and export markets is high. Development of this sector and improving the quality and safety of fruits and vegetables supplied to domestic and export markets is important because of the significant contribution it can make to increase the level of national income, generate new employment opportunities, increase farm income and enhance nutrition and health of the people. Controlling quality and assuring safety of fruits and vegetables supply chains is one of the most challenging issues in Sri Lanka.

6.2 Findings on Quality Issues related to Post-harvest Losses in Fruit and Vegetable Supply Chains

In Sri Lanka considerable quantities of fruits and vegetables produced go waste owing to improper post-harvest operations and lack of processing which result in a considerable gap between gross production and net availability. Studies showed that the post-harvest losses of fruits varied 20-40 percent with the highest losses recorded for papaya and for vegetables it was 20-46 percent with the highest loss recorded for okra due to unsatisfactory packaging, lack of ventilation in the lorries, poor facilities for handling the produce in the Colombo wholesale market and the extreme traffic congestion and inordinate delays before unloading. PHL are also high in the country due to hot and humid climates and due to lack of awareness and knowledge of stakeholders in fruit and vegetable supply chains. However, the losses are minimum in supermarket chain which is two to six percent while five to ten percent in export chains. Every actor in the supply chain of fruits and vegetables has a role to play in assuring the quality and safety due to improper pre-harvest, harvesting, poor handling, poor logistical operations, inappropriate packaging, storage and transportation affect the quality of fruits and vegetables produced in Sri Lanka.

The causes of quality losses are physiological, pathological and mechanical in nature. It was found that losses using the traditional packages (sacks) ranged from 10-30 percent while losses were generally reduced to five percent or less using improved packages. Packaging must be easy to handle, easily stackable, not excessively heavy and of appropriate dimensions and shape to fit the transporting vehicle. Use of safe packaging was limited due to many constraints. Most common were limited availability of plastic crates, high cost of transportation, less load to be transported per journey and absence of assured mechanism of returning safe packages moving through the supply chain. Unlike for vegetables, safe packages are used for fruits such as mango, papaya and guava. Mostly used safe packages were plastic crates, corrugated fiberboard boxes and wooden boxes.

6.3 Findings on Quality Issues related to Safety Issues in Fruit and Vegetable Supply Chains

In addition to post-harvest losses, food adulterations with harmful chemicals, pesticide residues and pathogenic risks, poor hygienic management in fruits and vegetables supply chains are the main factors which pose health hazards in the country. The consumers are reluctant to buy fruits and vegetables exposed to chemicals.

Factors threatening the safety of fruits and vegetables include naturally-occurring toxicants, natural contaminants such as fungal toxins (mycotoxins) and bacterial toxins and heavy metals (arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr)); environmental pollutants; pesticide residues and microbial contamination. The problem of contamination of food sources, especially vegetables by pesticide residues constitutes one of the most serious challenges to public health. However, the extent to which the population of Sri Lanka is exposed to food contamination by toxic heavy metals is not widely available.

In Sri Lanka, pesticides and fertilizers are extensively used than the recommended level by the DOA. Farmers assume that higher usage produces higher yield. On the contrary, overuse of fertilizers result in leaching while polluting the groundwater. Research highlighted the malpractices and misuse of pesticides by farmers. Pesticide usage is not properly regulated due to ineffective legislation, poor awareness and technical know-how among the farming community in Sri Lanka. According to the literature, issues related to pesticides are use of overdoses, application at shorter intervals, non-compliance to the withholding period, application of cocktail of pesticides, ignorance of the users, lack of motivation, lack of proper and adequate media campaign, exploitation by the agents of the pesticides suppliers and absence of proper monitoring systems in pesticide usage in the country. Farmers have inadequate information and knowledge on the safe and effective use of pesticides.

There is no long term systematic pesticide monitoring programme in Sri Lanka and little research has been carried out on contamination of food and water by pesticides.

In Sri Lanka, the task of ensuring food safety is conducted in a rather adhoc manner, tasks are dispersed to a number of government agencies and departments such as the Department of Agriculture, the Consumer Affairs Authority, the Sri Lanka Standards Institute, Atomic Energy Authority, Sri Lanka Customs – Quarantine Department and the Ministry of Health based on their respective areas of expertise. Lack of national standards to measure food safety and absence of an effective institutional mechanism to enforce food safety at different stages in the food chain affect the process.

The testing infrastructure in the country falls under different Ministries. Sri Lanka Standards Institute and the Industrial Technology Institute falling under the purview of the Ministry of Technology and Research lead the standardization process. In

addition, to other state-affiliated labs there are private companies (eg. SGS Lanka Pvt Ltd) that undertake testing and certification in exporting.

The official inspection service under the FCAU lacks satisfactory coordination and integration with other government agencies that are part of the local food chain. Especially the PHIs have no legal mandate to inspect the conditions of agricultural produces and their supplies. Also, the peripheral food inspectors of PHIs have to accomplish a wide spectrum of work load in their duty pertaining to a large locality.

Use of synthetic chemicals in inducing ripening is a typical problem in Sri Lanka as different types of liquid plant growth regulators containing 'ethephon' as an active ingredient are sprayed on the fruit or the fruits are dipped into the solution of ripening chemicals. Although by Section 26 of the Food Regulation of 1993 the use of calcium carbide is explicitly prohibited, it is the commonly used chemical by collectors and traders. Excessive use of commercial grade calcium carbide results in direct contact with carcinogenic compounds such as arsenic and phosphorous hydrides.

For export of fruits and vegetables, WTO's agreements on application of Sanitary and Phytosanitary (SPS) measures and agreement on Technical Barrier to Trade (TBT) are important requirement in international trade on food safety. For export of fruits and vegetables, it is important to follow GAP, GMP, ISO 9001 quality management system and HACCP standards.

Sri Lanka Standards for fruits and vegetables, leafy vegetables to control microbial, chemical and physical hazards associated with all stages from production to packaging of fruits and vegetables have been formulated by the SLSI. When chemicals and pesticides are used they should be in accordance with relevant legislative including the Regulations made under the Food Act No. 26 of 1980, Consumer Affairs Authority Act No. 09 of 2003 and the Control of Pesticide Act No. 33 of 1980.

Sri Lanka Food Act No. 26 of 1980 is the main national level legislative document related to food and food safety in Sri Lanka. The Food Advisory Committee is responsible for all administrative activities of the Food Act, food related policy issues and new developments. The main law covering food safety is basically implemented through the Director Health Services and the through local authorities and respective MOH offices in the region.

The quality and safety of fruits and vegetables produced in Sri Lanka suffer from improper pesticide and fertilizer use, poor methods and practices starting from the production stage to post-harvest measures. There is minimal intervention at the production or growing stage to ensure quality and safety.

6.4 Recommendations to Improve the Quality and Safety in Fruit and Vegetable Supply Chains

From the above reviews it is clear that there are true concerns over the consumption of poor quality and unsafe fruits and vegetables. Adoption of improved practices and prevention of contamination at various stages of horticultural chains are the best options for maintaining quality and safety.

From the foregoing discussion, it is clear that emphasis should be given to formulate national policy to minimize post-harvest losses of fruits and vegetables and the government would take initiatives and allocate resources to improve the post-harvest handling conditions and thereby improve the socio-economic status of the stakeholders in the fruit and vegetable supply chains.

Lack of storage facilities at market places is a leading issue for high post-harvest losses and for the quality of the produce. Therefore, upgrading the infrastructure facilities of existing wholesale and retail markets and establishing pack house facilities at existing collecting centres and Dedicated Economic Centres are necessary.

Improper handling in transportation and poor packaging practices lead to high post-harvest losses in fruits and vegetables. It is important to take measures such as introducing appropriate packages for different crops, provision of concessionary credit facilities to acquire improved packages and use of wrapping papers and box liners when transporting. In addition, state government refrigerated transportation system can be set up for fruits and vegetables transport and refrigerated vans can be initiated in rural areas by public - private partnership.

As the high-value product value chain is more demanding in food safety and quality standards, greater attention is required for certification and quality enforcement. Initiatives are needed to improve controls over pesticide use, improve food safety standards and reduce contamination. Recently the Registrar of Pesticide in a Gazette has issued MRLs for fruits and vegetables and with that new regulations can be introduced to prohibit sale of fruits and vegetables containing residues of pesticides.

Continued research to develop easy-to-use practical testing kits to identify chemicals, pesticides, additives, preservatives and toxic elements at the production, processing, distribution and consumption levels is essential. To go along with the increasingly important food safety requirements for high-value products, investments are needed in laboratory and testing infrastructure to match international standards. At present the food laboratories under SLSI and ITI are accredited by SLAB. It is important to set up accredited network of laboratories with skilled manpower to conduct scientific testing for the perishable agricultural commodities. Accreditation is important which ensures the competence of laboratories for reliable and technically valid test results.

Improved pre- and post-harvest practices are crucial in managing quality and assuring safety of horticultural produce in supply chain. Thus adequate measures must be taken at every step of the supply chain from production through harvesting, post-harvest handling, processing, packaging, storage and marketing of produce. To start with, the GAP (Good Agricultural Practices) need to be in place to produce and market good quality fruits and vegetables.

In spite of having strict laws and acts, inclination toward the use of artificial ripening agents is high among farmers and the vendors. Enforcing strict policies, laws and regulations on artificial fruit ripening is vital. In order to meet international safety standards in the modern market, lack of scientific ripening chambers is a problem as artificial ripening by the use of toxic and banned chemicals are mostly used for fruit ripening.

Majority of consumers concern on safety is high and on average the WTP (Willingness to Pay) is relatively high. Therefore, steps have to be taken to implement a cost effective safety assurance system for the greater satisfaction of consumers by the government with a separate market window to provide safe vegetables to consumers.

It is important to have a single apex regulatory authority known as Food Safety and Standards Authority in Sri Lanka to strengthen food safety regulations. Food Safety and Standard Act and food safety laws should be strengthened. It is important for the local government to adopt and implement national food safety standards based on the international recommended Codex Alimentarius Commission standards and a code of practice. There should be separate personnel for food inspection who is knowledgeable in food science and technology for auditing and monitoring food safety management systems for fresh fruit and vegetable supply chains as the quality of food inspection service is lagging behind.

Strengthening domestic market for food safety standards is important prior to expecting the supply chains to adapt to international standards of food safety.

Farmers are to be educated and trained on personal hygiene along with safe application of pesticides and efficient spray technology to prevent contamination in fields. Programmes through mass media such as TV, radio, mobile SMSs to sensitize both farmers and all relevant stakeholders on the issues are timely. Training of farmers in selecting correct inputs and in post-harvest handling, including cleaning, drying, sorting and packaging at the farm gate; training in the area of food safety both for the domestic market and for international trade are important. As food handlers of the supply chains of fruits and vegetables are not aware or educated enough to follow globally accepted norms of safe food, there should be clear guidelines to meet the food standards.

Finally, to assure quality and safety in the horticultural chains in Sri Lanka various options should be left open such as:

- massive awareness-raising programme
- preparation and distribution of appropriate training materials (manual, leaflet, poster, short film, music video, etc.)
- capacity strengthening of the relevant departments (DOA, universities, research institutes, etc.)
- capacity enhancement for analytical facilities (i.e. expansion of accredited laboratories)
- adoption of improved practices during production and post-production stages of the supply chain (pre-harvest use of inputs, harvest maturity and harvesting methods, sorting, grading, washing, packaging, transportation and storage)
- consumer awareness with regard to purchasing criteria, handling, processing for cooking, cooking, storage, food borne hazards
- research and training in relation to risk assessment, risk prevention, risk control, risk exposure
- reliable and quick analytical method for chemical residues and microbial contamination
- co-ordination among relevant ministries
- selection of competent personnel for various activities
- create facilities for short, medium or long-term preservation of perishables (for instance, cool stores or various other applicable techniques for shelf life extension)

Adopting the following roadmap of food safety (Figure 6.1) to assure food safety from the beginning of farmers' themselves through "Farm to Fork" approach is necessary in food control measures which include farmers and growers, manufacturers and processors, food handlers and consumers. Every stakeholder along the supply chain of fresh produce involved in harvesting, handling and marketing has a role to play in assuring the safety and quality of fresh produce. There must be a documented comprehensive national food safety policy and a plan of action involving all relevant stakeholders from farm to table and this food safety policy must be integrated into other areas of government policy such as poverty eradication and agricultural development.

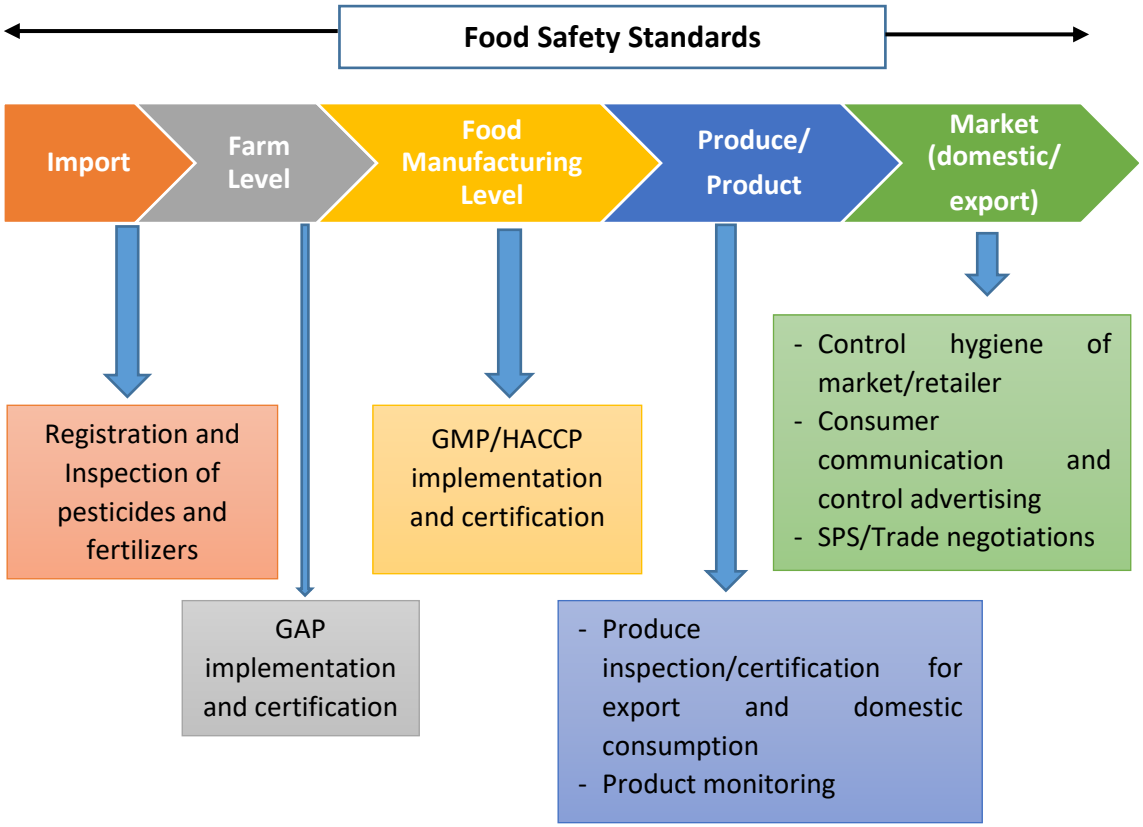


Figure 6.1: Roadmap of Food Safety

Table 6.1: Summary of Key Quality and Safety Issues, Underlying Factors and Recommendations in Fruits and Vegetables Supply Chains in Sri Lanka

Key Issue	Underlying Factors	Recommendations
Pre-harvest practices affect poor quality fruits and vegetables	- Poor quality planting materials - Pre-harvest diseases	- Pre-harvest fungicide treatments, sanitation, bagging and other field management practices are important.
Improper harvesting practices	- Harvesting at incorrect stage of maturity - Harvesting at incorrect time of the day - Use of improper methods	- Use of improved harvesting tools - Training of farmers
Lack of sorting and grading practices	- Farmers sell their products without sorting and grading in conventional channels - Only manual sorting is practiced in all conventional and improved channels	- Training of farmers
Lack of pre-treatment practices	- Pre-treatment procedures are only practiced by the exporters at present.	
Lack of storage facilities at market places	- Unprotected retail outlets at roadsides - At market places no space to store surplus supply for a reasonable time	- Upgrading the infrastructure facilities of existing wholesale and retail markets. - Establishing pack house facilities at existing collecting and Dedicated Economic Centres

Table 6.1 (contd.): Summary of Key Quality and Safety Issues, Underlying factors and Recommendations in Fruits and Vegetables Supply Chains in Sri Lanka

Key Issue	Underlying Factors	Recommendations
Improper handling in transportation and poor packaging practices	- PHL occur due to cuts, vibrations, abrasions, compression and impacts like mechanical damages during transport - Use of improper packages (polypropylene sacks and gunny bags) - Compressed packing into sacks - Overloading in lorries result in lack of ventilation in the lorries - Malpractices by both farmers and transporters - Rough handling during loading and unloading - Lack of refrigerated vehicles for the transportation - Expose to sunlight and rain - Use of improper trucks and lorries	- Introducing appropriate packages for different crops - Provision of concessionary credit facilities to acquire improved packages - Use of wrapping papers and box liners when transporting. - State government refrigerated transportation system can be set up for F & V transport. - Refrigerated vans can be initiated in rural areas by public- private partnership.
Lack of knowledge about the demand in the market		- Knowledge on demand forecasting
Improper practices in fruit ripening	- Use of industrial calcium carbide for ripening - Use of excess quantities	- Use of ethrel for ripening fruits instead of industrial calcium carbide - There should be specific laws to regulate artificial fruit ripening

Table 6.1 (contd.): Summary of Key Quality and Safety Issues, Underlying factors and Recommendations in Fruits and Vegetables Supply Chains in Sri Lanka

Key Issue	Underlying Factors	Recommendations
Pesticide Residues in vegetables	- Overuse of pesticides than the recommended level by farmers - Malpractices and misuse of pesticides by farmers - Harvesting of crops without considering the withholding period prescribed by the DOA - No proper monitoring system on pesticide usage	- Attitudinal change of farmers on pesticide usage. - Strengthening relationship between farmers and extension officers and encouraging farmers to seek pesticide, use instructions from Agriculture Extension Officers - Training for ARPAS on the selection of appropriate pesticides and dosage and training them to provide instructions to farmers. - Promote GAP programme. Awareness campaign for GAP programmes. Develop local market for GAP products. - Develop model farms with IPM - Strict enforcement of Pesticide Act and upgrading the existing food laboratories to carry out pesticide residue analysis - Development of GAP, GMP and HACCP for economically important fruits and vegetables - Improve testing and certification facilities

Source: Author's Information

LIST OF APPENDIX

Appendix Table 1: List of Banned and or Severely Restricted Pesticides in Sri Lanka with the Year of Implementation and the Year of Legal Declaration

Year (regulatory) Banned	Year (legally) Banned	Name of Pesticide (a.s.)
1970	2001 [a]	Endrin*
1976	2001 [a]	DDT*
1980	2001 [a]	Chlordimeform
1980	2001 [a]	Dieldrin*
1980	2001 [a]	Phosphamidon
1980	2001 [a]	Thalium sulphate
1984	2001 [a]	2,4,5-T
1984	2001 [a]	Ethyl-parathion
1984	2001 [a]	Methyl-parathion
1986	2001 [a]	Aldrin*
1986	2001 [a]	Lindane*
1987	2001 [a]	HCH (mixed isomers)*
1987	2001 [a]	Mercury compounds
1988	2001 [a]	Arsenic (arsenites & arsenates)
1988	2001 [a]	Heptachlor*
1988	2001 [a]	Leptops
1989	2001 [a]	Captafol
1990	2001 [a]	1,3-dichloropropane
1990	2001 [a]	Aldicarb
1990	2001 [a]	Quintozene (PCNB)
1994	2001 [a]	Petachlorophenol*
1994	2001 [a]	Chlordane*
1995	2001 [a]	Methamidophos
1995	-	Monocrotophos (60% SL restricted to use on red weevil in coconut)
1998	2001 [a]	Endosulfan (35% EC)*
2008	2014 [¶]	Paraquat (20% SL)
2011	2014 [¶]	Paraquat (6.5% SL)
2011	2014 [¶]	Dimethoate (40% EC)
2011	2014 [¶]	Fenthion (50% EC)
2011	2014 [¶]	Cyromazine (75% WP)
2012	2014 [¶]	Alachlor (36% EC)

Appendix Table 1 (contd.): List of Banned and or Severely Restricted Pesticides in Sri Lanka with the Year of Implementation and the Year of Legal Declaration

Year (regulatory) Banned	Year (legally) Banned	Name of Pesticide (a.s.)
2013	2014 †	Propanil (36% EC)
2013	2014 †	Carbofuran (3% GR)
2013	2014 †	Carbaryl (85% WP)
2013	2014 †	Chlorpyrifos (20% EC & 40% EC)
2014	2014 †	Glyphosate (36% SL)
2015	2015 §	Glyphosate (36% SL)

Source: https://www.doa.gov.lk/SCPPC/images/ROP/Tabel.pdf

* Classic organochlorine pesticides listed under the Stockholm Convention

[a]Ban of registration by the government extraordinary gazette No.1190/24 of 29.06.2001 under the Control of Pesticides Act No.33 of 1980.

[¶]Ban of registration by the government extraordinary gazette No.1854/47 dated 21.03.2014 under the Control Pesticides Act No.33 of 1980.

†Regional restriction for sale, offer for sale and use as per the government extraordinary gazette No.1894/4 of 22.12.2014 under the Control Pesticides Act No.33 of 1980.

§Ban of importation by the government extraordinary gazette No.1813/14 of 05.06.2013 under the Import and Export (Control) Act No.01 1969.

REFERENCES

Abeysekera, T. and Abeysekera, S. (n.d.) "Alternative Supply Chain Management Practices and the performance of Marketing Channels in Fruit and Vegetable Marketing in Sri Lanka", Market Analysis. Food and Agriculture Organization of the United Nations. Available at: http://www.ftp://ftp.fao.org/docrep/fao/010/ah996e/ah996e02.pdf [Accessed 14 October 2016].

Acedo, J.A.L. and Easdown, W. (2015) "Post-harvest Losses of Vegetables in South Asia", *Palawija Newsletter*, 32(2). Available at: http://www.uncapsa.org/sites/default/files/pn1508.pdf [Accessed 14 October 2016].

Acedo, Jr. A.L. and Weinberger, K. (2009) "Economic Practices of Postharvest Technologies for Vegetables", in Proceedings, held on 19-21, August, 2008, in Cambodia.

Adhikari, S. (2006) "Nepal – Country Paper", *Proceedings of the Seminar on Postharvest Management of Fruit and Vegetables in the Asia-Pacific Region*, India 5–11 October 2004 and Iran 23–28 July 2005, Asian Productivity Organization (APO). Available at: http://www.apo-tokyo.org/00e-books/AG-18_PostHarvest/AG-18_PostHarvest.pdf [Accessed 28 November 2016].

Adikaram, N. K. B. (Undated) A Multidisciplinary Approach to Reduce Post-Harvest Losses in Fruits due to Disease, National Science Foundation, Sri Lanka.

Amarakoon, R., Illeperuma, D.C.K. and Sarananda, K.H. (1999) "Effect of Calcium Carbide Treatment on Ripening and Quality of Velleicolomban and Willard Mangoes", *Tropical Agricultural Research* 11, pp. 54-60.

Ashan, F. (2004) "Country Paper-India". *APO Seminar on Reduction of Post-harvest Losses of Fruit and Vegetables*, Tokyo, Japan, October 2004. In: Rolle, R.S. eds. Asian Productivity Organization (APO). pp. 5–11.

Bandara, S.T.J. (Undated) "How to Identify Fruits and Vegetables free from Toxic Compounds", *Govikam* 1(47), Department of Agriculture, Sri Lanka.

Bhagwat, M.K. and Datar, A.G. (2014) "Enhancement of Shelf Life of Tomatoes by Postharvest Herbal Treatment, during Storage under Ambient Conditions", *Archives of Phytopathology and Plant Protection,* 47(10), pp. 1262–1273.

Brady, C.J. (1987) "Fruit ripening", *Annual Review of Plant Physiology and Plant Molecular Biology*, 38, pp. 155-178.

Central Bank of Sri Lanka (2016), "Annual Report – 2016".

Central Bank of Sri Lanka (2014), "Annual Report – 2014".

Central Bank of Sri Lanka (2014), "Annual Report – 2013".

Chandrasekara, A.I., Wettasinghe, A. and Amarasiri, S.L. (1985) "Pesticide Usage by Vegetable Farmers", *Annual Research Conference*, ISTI, Gannoruwa, Sri Lanka.

Choudhury, M. L. (2006) “Recent developments in reducing post-harvest losses in the Asia-Pacific region”, In: Rolle, R.S. eds. *Reduction of Postharvest Losses of Fruit and Vegetables*, Tokyo, Japan: FAO, Asian Productivity Organization (APO), October 2004, pp. 5-11.

Choudhury, M.L., Roya, S.K. and Kumar, R. (2004) “Current Status of and Recent Development in Post-Harvest Losses of Fruits and Vegetables in the Asia-Pacific Region”, In: Rolle, R.S. eds. *Reduction of Postharvest Losses of Fruit and Vegetables*, Tokyo, Japan: FAO, Asian Productivity Organization (APO), October 2004, pp. 5-11.

Dasika, R., Tangirala, S. and Naishadham, P. (2012) “Pesticide Residue Analysis of Fruits and Vegetables”, *Journal of Environmental Chemistry and Ecotoxicology*, 4(2), pp. 19-28. Available at: http://www.academicjournals.org/JECE [Accessed on 12 December 2016].

Democratic Socialist republic of Sri Lanka, Consumer Affair Authority Act, No. 3 (2003), March 21, 2003.

Department of Agriculture. (Undated) National Plant Quarantine Service. Available at: https://www.doa.gov.lk/SCPPC/NPQS/index.php/en/

Department of Agriculture (Undated) “Vegetable Varieties in Sri Lanka”. Available at: https://www.doa.gov.lk

Department of Census and Statistics. (2007-2016) “Extent and Production of Fruits and Vegetables”. Available at: http://www.statistics.gov.lk

Department of Census and Statistics. (2005-205) “Household Income and Expenditure Survey 2002, 2005, 2006/07, 2009/10 and 2012/13”. Available at: http://www.statistics.gov.lk

Dias, J.N.S. (1994) *Economic Importance of Post-Harvest Handling of Fruits and Vegetables in International Markets*, National Science Foundation, Sri Lanka.

Dharmasena, D.A.N. and Sarananda, K.H. (2012) *Present Status, Issues and Future Trends in Fruit and Vegetable Handling, Distribution and Marketing in Sri Lanka*. Available at: http://www.fruits.soton.ac.uk/files/2011/12/Srilanka-6-Slides-.pdf [Accessed 12 December 2016].

Din, A., Praveen, S., Ali, M.A. and Salam, A. (2011) “Safety Issues in Fresh Fruits and Vegetables: A Review”, *Pakistan Journal Food Science*, 21(1-4). Available at: http://www.psfst.com/__jpd_fstr/4c31ebc829cae2e3814bb09d1405f902.pdf [Accessed 5 January 2017].

Dissanayake, D.M.S.C. (2009) *Pesticide Residues Analysis of Tomato by using Gas Chromatography/Mass Spectroscopy*). Unpublished MSc Thesis, University of Sri Jayawardenapura, Colombo, Sri Lanka.

Dissanayake, C.A.K. (2015) “Evaluation of Present Status of using Safe Packages for Perishable Transportation”, Research Report, Institute of Postharvest Technology, Anuradhapura, Sri Lanka.

Ekanayake, S. and Bandara, L. (2002) “Development of Banana leather”, Annals of the Sri Lanka Department of Agriculture, 4, pp. 353-358.

Esham, M. and Usami, K. (2006) “Procurement Behavior of the Fruit and Vegetable Industry in Sri Lanka”, *Journal of Agricultural Sciences*, 2(3), pp. 36–44. Available at: http://www.doi.org/10.4038/jas.v2i3.8135 [Accessed 5 January 2017].

European Food Safety Authority (EFSA). (2010) “The 2010 European Union Report on Pesticide Residues in Food”. Available at: https://www.efsa.europa.eu/en/efsajournal/pub/3130 [Accessed 25 February 2017].

Export Development Board Sri Lanka. “Exports Statistics 2007-2015”. Available at: http://www.srilankabusiness.com

Fernando, M.F.S.W. and De Silva, P.H.J.C. (2000) “Post-harvest Handling of Mauritius Pineapple at Ambient Temperature”, Annals of Sri Lanka Department of Agriculture.

Fernando, M. (2006) “Sri Lanka – Country Paper”, *Proceedings of the Seminar on Postharvest Management of Fruit and Vegetables in the Asia-Pacific Region*, India 5–11 October 2004 and Iran 23–28 July 2005, Asian Productivity Organization (APO). Available at: http://www.apo-tokyo.org/00e-books/AG-18_PostHarvest/AG-18_PostHarvest.pdf.

Gazette of the Democratic Socialist Republic of Sri Lanka. “Food (Amendment) Act No. 20 (1991)”. Available at: http://www.203.94.76.60/FOODWEB/.../Food%20(Amendment)%20Act,%20No.%2020%20of%...

Gazette of the Democratic Socialist Republic of Sri Lanka. “Import and Export Control Act No. 1 (1969)”. Available at: https://www.parliament.lk/uploads/regulations/english/214.pdf

Gunaruwan, G. and De Silva, G. (2014) “Value Chain Analysis to improve the Quality and Safety of Fruits and Vegetables in Sri Lanka”, The Ceylon Chamber of Commerce, Trade Impact for Good.

Gunawardhana, H.P.G. and Liyanage, G.R. (1992) “Country Status Report on Pesticide Residues Sri Lanka”. Available at: http://www.192.248.98.23:8080/jspui/bitstream/123456789/890/.../ITIREPORT021_R203371.pdf [Accessed 15 November 2016].

Gunawardhane, C.R., Wasala, W.M.C.B., Dissanayake, C.A.K., Wijewardene, R.M.N.A., Chandrajith, U.G. and Thilakaratne, B.M.K.S. (2014), “Use of safe packaging for vegetable transportation on main supply chains in Sri Lanka”, *International Research Symposium on Postharvest Technology*.

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R. and Meybeck, A. (2011) “Global food losses and food waste”. Rome, FAO. Available at: http://www.fao.org/docrep/014/mb060e/mb060e00.pdf.

Hai, T.T. and Yen, T.V. (2006) “Vietnam – Country Papers”, *Proceedings of the Seminar on Postharvest Management of Fruit and Vegetables in the Asia-Pacific Region*, India 5–11 October 2004 and Iran 23–28 July 2005, Asian

Productivity Organization (APO). Available at: http://www.apo-tokyo.org/00e-books/AG-18_PostHarvest/AG-18_PostHarvest.pdf.

Haque, M.N., Saha, B.K., Karim, M.R. and Bhuiyan, M.N.H. (2009) "Evaluation of Nutritional and Physio-chemical Properties of Several Selected Fruits in Bangladesh", *Bangladesh Journal Scientific and Industrial Research*, 44(3) pp. 353-358.

Hassan, K. (2014) "Quality Management and Safety Assurance in Horticultural Chains of Bangladesh". *Journal of Agriculture, Livestock and Fisheries*, 1(1). Available at: http://www.banglajol.info/index.php/RALF/article/download/22346/15403

Hakim, M.A., Obidul Huq, A.K., Alam, M.A., Khatib, A., Saha, B.K., Haque, K.M.F and Zaidul, I.S.M. (2012) "Role of Health Hazardous Ethephon in Nutritive Values of Selected Pineapple, Banana and Tomato", *Journal Food Agriculture and Environment*, 10(2), pp. 247-251.

Halder, P. and Pati, S. (2011) "A need for paradigm shift to improve supply Chain management of fruits and vegetables in India", *Asian Journal of Agriculture and Rural Development*, 1(1), pp. 1-20.

Herath, G.M.L.K. (2005) "Factors causing Post-Harvest Quality Losses in Tomato, Brinjal and Snake Gourd at the Dambulla Dedicated Economic Center", Student Project Abstract 1995-2005, Department of Agriculture Extension, University of Peradeniys, Sri Lanka.

Herath, H.M.I., Bandara, D.C. and Abeysinghe Banda, D.M.G. (2000) "Effect of Calcium and Potassium Fertilizer Applied at the Time of Planting on the Control of Internal Browning under Cold Storage of Mauritius Pineapple", *Tropical Agricultural Research*, 12, pp. 352-359.

Hewajulige, I.G.N., Sivakumar, D., Sultanbawa, Y., Wijeratnam, R.S.W. and Wijesundera, R.L.C. (2006) "Effect of Chitosan Coating on Postharvest Life of Papaya var. Rathna grown in Sri Lanka", *Tropical Agriculture Research*, 18, pp. 135-142.

Hossain, M. F., Akhtar, S. and Anwar, M. (2015) "Health Hazards Posed by the Consumption of Artificially Ripened Fruits", *Bangladesh International Food Research Journal*, 22(5), pp. 1755-1760. Available at: http://www.ifrj.upm.edu.my

Hoque, M.A. (2012) "Action against Unscrupulous Fruit Ripeners, Financial Express", International Publications Limited, Dhaka, Bangladesh.

Huang, C. (2006) "China – Country Paper", *Proceedings of the Seminar on Postharvest Management of Fruit and Vegetables in the Asia-Pacific Region*, India 5–11 October 2004 and Iran 23–28 July 2005, Asian Productivity Organization (APO). Available at: http://www.apo-tokyo.org/00e-books/AG-18_PostHarvest/AG-18_PostHarvest.pdf.

Ilangakoon, A.U., Debarawatta, R.D.N., Edirisinghe, J.C. and Rathnayake, R.H.M.K. (2015) "Why Vegetable Wholeselers Ignore the use of Plastic Crates in Major Economic Centers in Sri Lanka", Proceedings of the 14th Agricultural Research Symposium.

Illeperuma, O.A. (2000) "Environmental Pollution in Sri Lanka: A Review", *Journal of National Science Foundation, Sri Lanka*, 28(4), pp. 301-325.

Islam, M.D., Mursalat, M. and Khan, M.S. (2016) "A Review on the Legislative Aspect of Artificial Fruit Ripening", *Journal of Agriculture and Food Security*, 5(8), Available at: https://agricultureandfoodsecurity.biomedcentral.com/articles/10.../s40066-016-0057-5

Jayalal, R. (2015) "Move to Transport Fruits, Veggies in Plastic Crates Opposed", *Sunday Observer*, 01 November 2015.

Jayathunge, K.G.L.R., Wasala, W.M.C.B., Rathnayake, H.M.A.P., Gunawardane, C.R., Smarakoon, H.C., Fernando, M.D. and Palipane, K.B. (2011) "Evaluation of different types of Packages for Handling and Transportation of Vegetables". Available at: http://www.ipht.lk/.../Wasala/Evaluation%20of%20different%20types%20of%20packaging.pdf

Jayas, D.S. and Jeyamkondan, S. (2002) "Review Paper on Modified Atmosphere Storage of Grains, Meats, Fruits and Vegetables", *Journal of Bio Systems Engineering*, 82(3), pp. 235-251.

Jayasinghe, S.N. (2009) *ISO 22000 Food Safety Management System in Sri Lanka Context*, Unpublished Undergraduate Thesis, University of Sri Jayawardhanapura, Sri Lanka.

Jayasooriya, P. M. (2002) *Modified Atmosphere Storage and Osmo-air Dehydration of Mango (Karuthacolomban)*. Unpublished M.Phill. Thesis. Post Graduate Institute of Agriculture, University of Peradeniya, Sri Lanka.

Jayathilake, H. M.U., Sarananda, K. H. and Jayasekara S. J. B. A. (2009) "Effect of Bagging on Postharvest Quality of Mango var. "Karuthacolomban", Proceedings of 9th Agricultural Research Symposium, pp. 341-345.

Jonker, T.H., Ito, H. and Fujishima, H. (2004) "Food Safety and Quality Standards in Japan: Compliance of Suppleirs from Developing Countries", *Agriculture and Rural Development Discussion Paper*, World Bank. Available at: http://www.siteresources.worldbank.org/INTRANETTRADE/.../Standards/JapanCountrySurveyF.... [Accessed 14 November 2016].

Kader, A.A. (2004) "The Role of Post-Harvest Management in Assuring the Quality and Safety of Horticultural Produce", *FAO Agricultural Services Bulletin*, Food and Agriculture Organization of the United Nations, Rome.

Kananke, T., Wansapala, J. and Gunaratne, A. (2014) "Heavy Metal Contamination in Green Leafy Vegetables Collected from Selected Market Sites of Piliyandala Area, Colombo District, Sri Lanka", *American Journal of Food Science and*

Technology, 12(5), pp. 139-144. Available at: http://www.pubs.sciepub.com/ajfst/2/5/1 [Accessed on 25 May 2017].

Kanlayanarat, S. (2007) "Postharvest Technologies for Fresh Leafy Vegetables in Thailand", *Workshop Proceedings on Best Practices in Postharvest Management of Leafy Vegetables in Greater Mekong Sub-region Countries*, 25-27 October 2007, Vietnam.

Karunagoda, K., Rajapakse, R.D.D.P., Ayoni, V.D.N. and Rambukpitiya, S.D. (2011) "Post-harvest Losses of Up-country Vegetables in Sri Lanka". *Annals of the Sri Lanka Department in Agriculture, 2011*. Research News, 13.

Keikotlhaile, B. M., and Spanoghe, P. (2011) "Pesticide Residues in Fruits and Vegetables", Ghent University Belgium. Available at: https://www.researchgate.net/.../221910239_Pesticide_Residues_in_Fruits_and_Vegetabl...

Kitinoja, L. (2013) "Use of Cold Chains for reducing Food Losses in Developing Countries", PEF White Paper No. 13-03, The Postharvest Education Foundation. Available at: http://www.postharvest.org/Use%20of%20cold%20chains%20PEF%20white%20paper%2013-03...

Kriesemer, S.K., Weinberger, K.M. and Chadha, M.L. (2009) "Demand for and Awareness of Safely Produced Vegetables in India", Results of a scoping study conducted in November-December 2009. AVRDC: The World Vegetable Centre Research in Action. 10(74), pp. 1–15.

Krishnapillai, N., Herath, H.M.W. and Wijeratne, D.B.T. (1996) "Postharvest Changes in three Varieties of Mango as Affected by Pre and Postharvest Treatments", *Tropical Agricultural Research*, 8, pp. 3I5-325, Post Graduate Institute of Agriculture, Sri Lanka.

Kumarasinghe, W.N.T. (2011) *Retail Mobile Stall for Extending the Shelf Life of Selected Fresh Fruits and Vegetables*, Unpublished Undergraduate Thesis, Department of Agriculture Systems, Faculty of Agriculture, University of Rajarata, Sri Lanka.

LaGra J. (1990) "A Commodity Systems Assessment Methodology for Problem and Project Identification", Inter-American Institute for Cooperation on Agriculture Postharvest Institute for Perishables, ASEAN Food Handling Bureau.

Madakumbura, E.G.I.S.N., Wijewardhana, R.A.N.A. and Prasanna, P.H.P. (2008), Effect of Oxalic Acid, Ethanol Vapor and Packaging on Post-harvest Performances of *Carica papaya* (Variety Red Lady), Abstracts of final year research-2008, Faculty of Agriculture, Rajarata University of Sri Lanka.

Madusanka, B. (n.d) "Food Control Management in Sri Lanka". Available at: http://www.academia.edu/6511533/Food_Control_Management_in_Sri_Lanka [Accessed 10 October 2016].

Marasinghe, M.A.M.N. (2001) "*Effect of Harvesting Maturity, Packing Material and Hot Water Treatment on "Green Island" Formation of 'Rathna' variety of Papaya"*, Unpublished BSc Thesis, Post Graduate Institute of Agriculture, Peradeniya, Sri Lanka.

Marasinghe, J.P., Magamage, C., Shiromi, M.G.D. and Aravinda, A.G.P. (2011) "Organophosphate Pesticide Residues in Food Commodities in Sri Lanka: A Review", *Annals of the Sri Lanka Department of Agriculture 2011*, 13, pp. 81-93.

Ministry of Agriculture (2015) "National Food Production Programme 2016-2018", Ministry of Agriculture, Sri Lanka.

Ministry of Health (2011) "Food Based Dietary Guidelines for Sri Lanka", Nutrition Division, Ministry of Health.

Mubarak, A.M. (2014) "Pesticide Residue Trials on Selected Vegetable Crops",

Organization for Economic Corporation and Development (OECD). (2003) "Guidance on Pesticide Compliance and Enforcement Best Practices". Available at: https://www.oecd.org/env/ehs/pesticides.../Pesticides_Compliance_Guidance.pdf

Othman, N.M. (2007) "Food Safety in Southeast Asia: Challenges Facing the Region", *Asian Journal of Agriculture and Development,* 4(2). Available at: http://www.ageconsearch.umn.edu/bitstream/166014/2/AJAD_2007_4_2_6 Othman.pdf

Padmajani, M.T., Aheeyar, M.M.M. and Banadara, M.A.C.S. (2014) "Assessment of Pesticide Usage in Up Country Vegetable Farming in Sri Lanka", Research Report, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Pandiarajan, T. and Tajuddin, A. (2014) "Studies on Pre-Cooling of Tomato", *Journal of Agricultural Mechanization in Asia, Africa and Latin America*, 45(3). Available at: https://www.researchgate.net/.../287316552_Studies_on_Pre-Cooling_of_Tomato [Accessed 15 January 2017].

Parliament of the Democratic Socialist Republic of Sri Lanka, "Food Act No. 26 of 1980". Available at: http://www.203.94.76.60/FOODWEB/.../Food%20Act...%2026%20of%201980/Food%20Act,%2...

Parliament of the Democratic Socialist Republic of Sri Lanka, Plant Protection Act No. 35 (1999). Available at: http://www.extwprlegs1.fao.org/docs/pdf/srl37310.pdf

Parliament of the Democratic Socialist Republic of Sri Lanka, Consumer Affairs Authority Act No. 09 (2003). Available at: http://www.caa.gov.lk/web/images/pdf/act.pdf

Parliament of the Democratic Socialist Republic of Sri Lanka, Control of Pesticides Act No. 33 (1980). Available at: https://www.doa.gov.lk/.../act/pesticides/control_of_pesticides_act_no_33_of_1980.p...

Parliament of the Democratic Socialist Republic of Sri Lanka, "Food (Amendment) Act No. 29 (2011). Available at: http://www.203.94.76.60/FOODWEB/.../Food%20(Amendment)%20Act...29.%20of%202011/Fo...

Perera, M., Kodithuwakku, S.S. and Weerahewa, J. (2004) "Analysis of Vegetable Supply Chains of Supermarkets in Sri Lanka", *Sri Lankan Journal of Agricultural Economics*, 6(1), pp. 67-81.

Peris, H.M.S. and Sarananda, K.H. (2005) "New Consumer Packs Reduce Post-Harvest Losses of Vegetables", *Annals of the Department of Agriculture*, 7, p. 391.

Prakash, T.N. (2003) "A Theoretical Framework to Promote Organic Produce Marketing in India"*, Indian Journal of Agricultural Marketing,* 17(3), pp. 1-16.

Prasad, H. U. K. C. (2005) *Prolong the Post-Harvest Life of Papaya Using Modified Atmosphere Packaging and Waxing*, Unpublished BSc Thesis, University of Ruhuna, Sri Lanka.

Prasad, B. (2015) *Postharvest Analysis of Vegetables in Fiji Eggplant, Okra and Tomato*, Unpublished Master Thesis, Faculty of Business and Economics, University of the South Pacific, March, 2014.

Priyadarshana, D. and Jayasinghe, U. (2016) "An Evaluation of Selected Dedicated Economic Centers: Comparative Analysis in Norochcholei and Nuwara Eliya", Working Paper, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Ranasingha, M.G.P. (2006) *Extension of Post-Harvest Life of Fresh Banana Bunches using Modified Atmosphere Package under Ambient Condition*, Unpublished BSc Thesis, Faculty of Agriculture, University of Ruhuna, Sri Lanka.

Ranasinghe, R.A.D.D.N. (1997) *Factors Influencing Postharvest Longevity of Okra*, Unpublished Master Thesis, Post Graduate Institute of Science, Peradeniya, Sri Lanka.

Ranathunga, R.A.N.T., Karunagoda, K.S. and Fernando, A.P.S. (2009) "Post-Harvest Losses in Up Country Vegetables", Undergraduate Research Symposium, University of Rajarata, Sri Lanka.

Ranaweera, S. (2008) "Development of Organic Agriculture Sector in Sri Lanka". Available at: http://www.asiantribune.com/?q=node/10186 [Accessed 18 August 2016].

Ranaweera, K.K.D.S. and Bamunuarachchi, A. (2005) "Quality Characteristics of Processed Food: Vacuum between the Said and Actual Situation". *Proceedings of the Symposium on Agro-processing Industries in Sri Lanka: Potentials and Constraints*, HARTI October 2005, Sri Lanka.

Ratnapala, D.G.S. and Peiris, B.C.N. (1994) “Effect of Harvesting Stage and Storage Condition on Storage Life of Okra”, *Tropical Agricultural Research*, 6, pp. 1-16.

Registrar of Pesticide, Department of Agriculture. “List of Banned and or Severely Restricted Pesticides in Sri Lanka with the Year of Implementation and the Year of Legal Declaration”, Available at: https://www.doa.gov.lk/SCPPC/images/ROP/Tabel.pdf

Risvy, H.M.M. and Thanaraj, T. (2011) *Comparison of the Performance of Different Mango Harvesting Devices*, Unpublished Undergraduate Thesis, Faculty of Agriculture, Eastern University, Sri Lanka. Available at: http://www.fag.esn.ac.lk/agrieast/volume_5/4.pdf

Rodrigo, T.M.P.S. (2009) *Consumers’ Perception on Safety of Vegetables and their Willingness to Pay*, Undergraduate BSc Thesis, Faculty of Agriculture, Rajarata University of Sri Lanka, Anuradhapura.

Rolle, R. S. (ed.) (2006) “Improving Postharvest Management and Marketing in the Asia-Pacific Region: Issues and Challenges Trends in the Fruit and Vegetable Sector”, Tokyo, Japan: FAO, Asian Productivity Organisation (APO).

Rupasena, L.P., Perera, I.R. Chandrasiri, J.K.M.D. and Rathnayake, B. (1999) “Vegetable Production and Marketing in the Nuwara Eliya District”, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Rupasena L.P., Rathnayake, B. and Ravichandran, T. (2001) “Study of Agricultural Marketing Information Systems (Matale district)”, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Sarananda, K.H. (2000) “Appropriate postharvest technologies for horticultural crops in Sri Lanka”, Report of the APO seminar on Appropriate Postharvest Technologies for Horticultural Crops held in Bangkok from 5-9 July 1999.

Sarananda, K.H. (2008) “Pre-harvest Calcium Spray in Incidence of Internal Browning in Pineapple (cv. Mauritus) during Cold Storage”, *AGRIEAST, Journal of Agriculture Science*, 7, pp. 1-8, Eastern University of Sri Lanka.

Sarananda, K.H. and Amarakoon, R. (1999) “Methods to Minimize Postharvest Rot of Three Local Cultivars of Mango”, Annual Symposium of the Department of Agriculture, 21-22 September 1999.

Sarananda, K.H. and Wijerathnam, R.S.W. (1994) “Controlled Atmosphere Storage of ‘Embul’ Bananas”, *Tropical Agricultural Research*, 6, pp. 17-22.

Sarananda, K.H.**,** Wijesinghe, W.A.J.P., Dulani, H.N. and Peiris, C.N. (2004) “Effect of Hot Ethral Dip Treatment for Improving Peel Colour Development and Reducing Stem End Rot of Karuthacolomban Mango”, Annals of the Sri Lanka Department of Agriculture, 6, pp. 187-194.

Sarananda, K.H., Balasuriya, S.T. and Ganeshalingam, K. (2004) “Quality of Papaya Variety ‘Ratna’ as affected by Post-Harvest Handling”, *Tropical Agricultural Research and Extension*, 7, pp.72-78.

Sarananda, K.H., Wijesinghe, W.A.J.P., Dulani, H.N. and Peiris, C.N. (2004) “Effect of Hot Ethral Dip Treatment for improving Peel Color Development and Reducing Stem end rot of Karuthacolomban Mango”, *Annals of the Sri Lanka Department of Agriculture*, 6, pp. 187-194.

Sarananda, K.H. and Wijesooriya, M.W.M.A.G. (2008) “Postharvest Technology of Fruits”, Department of Agriculture, Peradeniya, Sri Lanka.

SATNET Asia (2014) “Postharvest Management and Market Linking for Vegetables and Fruits in South Asia”, Regional Training Programme, India 26-28 November, 2014.

Senavirathna, W.M.I., Sarananda, K.H. and Jayasekera S.J.B.A. (2009) “Post-harvest Life of Two Leafy Vegetables as affected by Harvesting Time of the Day”, *Proceedings of 8th AGRES*, Wayamba University of Sri Lanka.

Siddiqui, M.W. and Dhua, R.S. (2010) “Eating Artificially Ripened Fruits is Harmful”, *Journal of Current Science*, 99(12). Available at: https://www.researchgate.net/.../229429873_Eating_Artificially_Ripened_Fruits_is_H... [Accessed 3 March 2017].

Srithamma, S., Vithayarungruangsri, J. and Posayanonda, T. (2005) “Food Safety Programme: A Key Component for Health Promotion”. Available at: http://www.fda.moph.go.th/project/foodsafety/HealthPromotion2.pdf

Sirivatanapa, S. (2006) “Packaging and Transportation of Fruits and Vegetables for Better Marketing”. Postharvest Management of fruit and vegetables in the Asia-pacific Region. Food and Agriculture Organization of the United Nations Agricultural and Food Engineering Technologies Service, Rome.

Subramanian, K.S., Sekar, C., Meneka, S. S. and Prakash, L.V. (2015) “Reducing Post-Harvest Losses in Mango in South Asia”. Available at: http://www.idrc.ca/EN/Documents/Reducing-post-harvest losses-in-mango-in-South-Asia.pdf

Selvarajah, S., Herath, H.M.W. and Bandara, D.C. (1999) “Basal Application of Fused Magnesium Phosphate (FMP) on the Incidence of Post-Harvest Internal Browning of Mauritius Pineapple”, *Tropical Agricultural Research*, 11, pp. 432-437.

Sri Lanka Standards Institution (2016) “Good Agricultural Practices (GAP) for Fruits and Vegetables (SLS 1523-1:2016), Sri Lanka Standards Institute, Colombo, Sri Lanka.

Sri Lanka Standards Institution (2016) “Code of Hygienic Practices for Fresh Leafy Vegetables (SLS 1524: 2016)”, Sri Lanka Standards Institute, Colombo, Sri Lanka.

Subramanian, K.S., Sekar, C., Meneka, S. S. and Prakash, L.V. (2015) “Reducing Post-harvest Losses in Mango in South Asia”, Available at: http://www.idrc.ca/EN/Documents/Reducing-post-harvest losses-in-mango-in-South-Asia.pdf

Techawongstien, S. (2006) “Thailand – Country Paper”, *Proceedings of the Seminar on Postharvest Management of Fruit and Vegetables in the Asia-Pacific Region*, India 5–11 October 2004, Iran 23–28 July 2005, Published by Asian Productivity Organization (APO). Available at: http://www.apo-tokyo.org/00e-books/AG-18_PostHarvest/AG-18_PostHarvest.pdf.

Thantirige, M.K. (1993) *Effects of Quantitative and Qualitative Postharvest Losses of Mango and Passion Fruit*, Unpublished MSc Thesis, Post Graduate Institute of Agriculyure, University of Peradeniya, Sri Lanka.

Thantirige, M., Pieris, B.C.N. and Senanayake, Y.D.A. (1993) *Qualitative Postharvest Losses in Mango*, Unpublished Post Graduate Thesis, Post Graduate Institute of Agriculture, Sri Lanka.

United Nations Conference on Trade and Development (UNCTAD) (2007) “Safety and Quality of Fresh Fruit and Vegetables: A Training Manual for Trainers”. New York and Geneva, United Nations, 2007. Available at: http://www.unctad.org/en/docs/ditccom200616_en.pdf

Veena, B.K. N. and Venkatesha, H. R. (2011) “Supply Chain: A Differentiator in Marketing Fresh Produce”, *IUP Journal of Supply Chain Management*, 8(1), pp. 23-36.

Vidanapathirana, R. and Wijesooriya, N. (2014) “Export Market for Organic Food: Present Status, Constraints and Future Scope”. Research Report, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Vidanapathirana, R. (2008) “Marketing Margins of the Domestic Vegetable Trade in Sri Lanka”, *Sri Lanka Journal of Agrarian Studies*, 12(2), pp. 36-60, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Vidanapathirana, R., Priyadarshana, D. and Rambukwella, R. (2008) “Marketing of Vegetables through Supermarkets: Implication of Procurement Practices for Farmers”, Research Report, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Wanniarachchi, S.D.R., Wickramasinghe, C.D., Wellala, C.K.D. and Karunathilake, M.S. (2009) “Impact of Boron and Calcium on Internal Browning of Banana”, *Annals of Sri Lanka Department of Agriculture, 2009*. 11, pp. 173-182.

Wasala, W.M.C.B., Dharmasena, D.A.N., Dissanayake, T.M.R. and Thilakarathne, B.M.K.S. (2015) “Vibration Simulation Testing of Banana Bulk Transport Packaging Systems”, *Tropical Agricultural Research*, 26(2), pp. 355-367, Post Graduate Institute of Agriculture, University of Peradeniya, Sri Lanka.

Wasala, W.M.C.B., Dissanayake, C.A.K., Dharmasena, D.A.N., Gunawardane, C.R. and Dissanayake, T.M.R. (2014) “Postharvest Losses, Current Issues and Demand for Postharvest Technologies for Loss Management in the Main Banana Supply Chains in Sri Lanka”, *Journal of Postharvest Technology*, 2(1), pp. 080-087.

Wasala, W.M.C.B., Gunawardhane, C.R., Rathnayake, R.N.R.N.K., Wijewardhana, R.M.N.A., Jayathunhe, K.G.L.R, Thilakarathne, B.M.K.S. and Wijerathne, D.B.T. (2012) "Study on Feasibility of Safe Packaging for economically important vegetable transportation", *International Symposium on Agriculture and Environment*, University of Ruhuna, Sri Lanka.

Wasala, W.M.C.B., Dharmasena, D.A.N., DIssanayake, C.A.K. and Thilakarathne, B.M.K.S. (2015) "Feasibility Study on Styrofoam Layer Cushioning for Banana Bulk Transport in a Local Distribution System", *Journal of Bio Systems Engineering*, 40(4), pp. 409-416.

Westgren, R. E. (1999) "Delivering Food Safety, Food Quality, and Sustainable Production Practices: The Label Rouge Poultry System in France". *American Journal of Agricultural Economics*, 81(5), pp. 1107-1111.

Wijewardane, R.M.N.A. and Thilakarathne, B.M.K.S. (2012) "Development of Composite Wax Formulation for Shelf Life Extension of Papaya". *International Symposium on Agriculture and Environment*, University of Ruhuna, Sri Lanka.

Wijewardane, R.M.N.A., Senevirathne, G.D., Jayawardana, N.W.I.A., Dissanayake, T.M.R., Wasala, W.M.C.B. and Thilakarathne, B.M.K.S. (2014) "Reduction of Postharvest Losses in Leeks during Transportation using Wooden Bulk Packages", *International Research Symposium on Postharvest Technology*.

Wijewardane, R.M.N.A. (2013) "Application of Polysaccharide Based Composite Film Wax Coating for Shelf Life Extension of Guava (Var. Bangkok Giant)", *Journal of Postharvest Technology*, 1(01), pp. 016-026.

Zaneer, S.M.M. (1998) *Pesticide Residue Trials on Selected Low Country Vegetables*, Unpublished MSc Thesis, Department of Chemistry, University of Colombo, Sri Lanka.