Using Quality Controlled Logistics Concept To Reduce Food Losses In Fresh Agri-produce Supply Chains

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Dedication

To my dear wife Tendai, my sons Zvikomborero & Simbarashe,
Thank you for giving me strength and energy to fly high whenever my wings forget how to fly.

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EXECUTIVE SUMMARY

Fresh agri-produce such as horticultural produce and floriculture produce are becoming increasingly popular in both domestic and international markets. These sectors have become important to the food security of most developing countries through their contribution to export earnings and incomes. However, there is a considerable amount of loss/waste that occurs in fresh agri-produce supply chains as a result of mechanical and physiological defects. These losses deprive exporters of potential revenue from export earnings and incomes. Hence, there is need to prevent or minimise these losses. This thesis contributes to the body of knowledge in the field of quality controlled logistics in agri-food supply chains by providing insight into the interdependence of contextual factors and level of quality controlled logistics required to reduce incidence of defects and losses in agri-produce supply chain.

Objective: This thesis explores how the principles of quality controlled logistics can be used to identify bottlenecks and solutions to achieving a higher level of quality control, logistics control that can result in reduced food losses in the fresh agri-produce supply chain. The assumption is that use of time-dependent quality information at identified critical control point to direct fresh agri-produce will help reduce incidence of defects in agri-produce supply chain. The hypothesis is that, *Lack of quality control and insufficient logistics control at identified critical control points contributes to high food losses especially in complex supply chain.*

Theory analysis: An extensive review of literature on pre-harvest and postharvest management of tropical fruits quality control and logistics control is carried out to gain a deep insight into the problem situation. Techno-managerial approach developed by Luning and Marcelis (2006) is be used to explain different theories from food technology and management science that can be used to analyse pre-harvest and postharvest factors that influence incidence of defects in the fresh agri-produce supply chain. From this literature analysis is was found out that mechanical and physiological defects are the main causes of losses in agri-fresh supply chain, with human handling being the main cause of mechanical defects that include bruises and extreme temperatures being the main cause for physiological defects such as chilling injury and physiological pitting.

Conceptual Framework and Research Model: A conceptual framework that gives an overview of pre-harvest and postharvest factors that influence the incidence of defects, critical control points in fresh agri-produce chains and logistical factors influencing incidence of defects is developed from the literature review. The conceptual model is used a backbone towards developing of a research model. A research model consisting of four elements; (i) quality controlled logistics (QCL) (ii), physical process and critical control points and, (iii) contextual factors, and (iv) outcome factors/performance indicators, is developed. The

element quality controlled logistics is further developed into three sub-elements; quality control, logistics control and an integration of the two by use of quality information. Four contextual factors; product characteristics, process characteristics, chain characteristics and market characteristics, adopted from MSc Thesis of Deelen (2009) are used. The research model was validated using two case studies. The outcome factor is percentage food loss due to defects. From the results obtained from the case studies, it is concluded the developed model has the potential to be used to assess level of quality controlled logistics in fresh agri-produce supply chain and also to provide a solutions on how to minimise food losses/waste in these supply chain. Identified weaknesses of the research model are that the indicators for quality controlled logistics are too general and also that more performance indicators/outcome factors need to be considered.

Methods: Two case studies, one in the cut flower cold supply chain (Kenya) and the second one in the banana fruit supply chain (Zimbabwe) were conducted to evaluate the developed research model. Interviews, questionnaires and participatory observations methods were used to collect data.

Results

The applicability of the research model developed in this study is evaluated using two case studies; cut flowers supply chain and a banana export food supply chain. Results from the two case studies show that level of quality controlled logistics is higher in the cut flower supply chain as compared to that in the banana supply chain and thsi was attributed to teh complexity of contextual factors in the flower supply chain as compared to teh complexity of contextual factors in the banana fruit supply chain. It is also evident from the results that contextual factors influence the level of quality controlled logistics in the chain. Indicators, *sophistication of identifying critical control points* and *sophistication in predictions of incidence of defects* scored low in both supply chains and contributed to low level of control in the sub-elements quality control and integration of quality control and logistics control respectively.

Conclusions

In conclusion, it can be said that the results from the case studies proved that a higher level of quality controlled logistics is required to reduce incidence of defects in fresh agri-produce chains that have complex contextual factors as compared to the chain with less complex contextual factors. These results are in line with findings of Van der Spiegel et al (2003) who reported that contextual factors have an influence level of control required to realise the desired quality performance. Based on these two case studies, the research model developed in this study is found to have the potential to be used to judge level of control in fresh agri-produce supply chain and also provide a way to help minimise losses/waste in these supply chains.

CHAPTER 1 INTRODUCTION

1.1 Overview on global production of tropical and subtropical fruit

Horticultural produce and processed products from the developing world are becoming increasingly popular in both domestic and international markets (Weinberger et al., 2008). The world production of tropical and subtropical fruits in 2004 was estimated at 67.7 million tonnes, of which 98% was produced in developing countries (FAO, 2004). The major tropical and subtropical fruits produced and traded included mango, pineapple, avocado and papaya, while minor fruits included rambutan, longan, mangosteen, lychees, carambola, passion fruit and guava. Mango was the dominant variety with a global output of 24.3 million tonnes and comprised 36% of world tropical fruit production. World production of pineapples reached 15.5 million tonnes or 23% of tropical fruit production, followed by papaya at 8.5 million tonnes (12.6 percept) and avocado at 3.3 million tonnes (4.8 percept). In 2003, fresh tropical fruit exports generated about US$ 2.3 billion, with US$ 1.1 billion being for pineapples alone. Comparative data for other fresh fruit traded internationally included US$ 4.8 billion for bananas, US$ 3.4 billion for apples, US$ 2.5 billion for oranges and US$ 1.1billion for pears (FAO, 2004).

Losses in tropical and subtropical fruit supply chains

While the tropics possess a diverse number of species of edible fruits, the climatic conditions also tend to hasten spoilage and quality, especially during the period after harvest (Weinberger and Lumpkin, 2007). Most tropical and subtropical fruits have a limited post-harvest life or shelf life due to their high perishability. Tropical and subtropical fruit contain 80-90% moisture and therefore suffer detrimental changes after harvest (Mitra, 2008). Kader (2002) and reported that about 15-20% of cumulative losses have been observed across tropical fruit supply chains leaving little quality surpluses for export and processing (Table 1). Kader and Rolle (2004) reported that in the United States, the losses of fresh fruits and vegetable are estimated to range from 2% for potatoes to 23% for strawberries, with an overall average of 12% losses between production and consumption depending on the commodity. These losses are enhanced by extended storage, higher temperature, low relative humidity, physical damage, and chilling injury (Kader, 2002).

Table 1: Estimated postharvest losses of fresh produce in developed and developing countries

Locations	Developed Countries		Developing Countries	
	Range (%)	Mean (%)	Range (%)	Mean (%)
From production to Retail sites	2-23	12	5-50	22
At retail, food service, And consumer sites	5-30	20	2-20	10
Cumulative total	**7-53**	**32**	**7-70**	**32**

Economic losses due to fruit defects

Losses due to fruit defects take place at various stages of handling, from harvesting until fruit reaches consumers (Ladaniya, 2008). Causes of fruit defects in tropical and subtropical fruits can be divided into two, those that occur during pre-harvest and those that occur during postharvest (Knee and Miller, 2002). Pre-harvest factors include climatic conditions, especially relative humidity, rain, temperature, cultivation practices, stage of fruit maturity, and fruit type. Postharvest practices such as harvesting, handling, packaging, storage, transportation and marketing greatly influence fruit losses (Paull and Chen, 2005).

In agriculturally developed countries such as Japan, the Republic of Korea and Taiwan Province of China, it has been reported that the post-harvest losses due to mechanical damage and other fruit disorders are about 10%. In the Philippines, post-harvest fruit losses due to mechanical damage range from 15 to 35%. Tropical fruit like papaya have been reported to suffer post-harvest losses of 30 to 60% (FAO, 2005). The Pakistan National Commission on Agriculture estimated that fruit defects and inadequate facilities in post-harvest handling, transportation, storage and marketing cause between 20 and 40% loss of fruit and vegetables (FAO, 2005). Jawkar et al (2005) reported losses amounting to 6% (775.68 tonnes) and 3% (1368.55 tonnes) in mango and kiwifruits respectively (Table 2) in Iran.

Table 2: Production rate, losses, export and import of some tropical fruits in Iran

Crop	Production rate (tons)	Losses (%)	Losses (tons)	Export
Banana	4056526	6	2433.915	0.000
Mango	12928	6	775.68	0.000
Orange	1878547.9	8	150283.83	7324.1
Tangerine	710002.59	9	63900.233	24879.7
Kiwi fruit	45618.45	3	1368.55	8728.5

On the Belgian market the auction price for degraded apples due to mechanical defects and physiological disorders is 1/3 of the normal price. A reduction of only 10% in degraded apples could have led to an income increase for the growers of 892,000 D in 2000 and 595,000 D in 2001 (Zeebroeck van et al., 2007). In Brazil, Chitarra and Chitarra, (2005) reported high post-harvest losses of fresh agri -produce of up to 50% of what is produced. In 2001, 15 million tons of vegetables were produced and more than 5 million tons were lost, enough to supply 53 million people and generate a loss more than US$ 1 million (Chitarra and Chitarra, 2005).

The presented literature show that there is a considerable amount of fruit losses/wastage that occur in tropical and subtropical fruit supply chains as a result of fruit defects. Tropical fruits are important to the food security of developing countries from both a nutritional standpoint and through their contribution to export earnings and incomes (FAO, 2004). Losses in tropical and subtropical fruit supply chain deprive exporters of potential revenue from export earnings and incomes. Reducing these postharvest losses could, presumably, add a sizeable quantity to the global food supply (Kader, 2002).

1.2 Quality Controlled Logistics

Quality control logistics can be simply described as an integration of quality control and logistics control. Quality control and logistics control are the two elements of quality controlled logistics (Annex E). Quality control involves measuring of product quality or process conditions, comparing to acceptable specifications or standards and taking correcting action if the measurements are out of the acceptable range. On the other hand, logistics control involves directing of products to the right place at the right time in the right quantity. Information exchange is key to the integration of these two elements is such a way that logistics activities in the chain are based on quality information about product properties. Quality controlled logistics makes use of variation in product quality and heterogeneous needs of customers and the possibilities to manage product quality in the distribution chain. Quality distribution profiles are made by batching products of the same quality at the beginning of the supply chain and product differentiation is done by timely separation during harvesting and processing stages (Van der Vorst et al., 2007b).

1.3 Research problem

The presented literature is the above sections show that there is a considerable amount of losses/wastage that occur in tropical and subtropical fruit supply chains as a result of defects. These losses deprive exporters of potential revenue from export earnings and incomes. It is essential to understand factors influencing incidence of these defects and also to identify critical control points the incidence of these defects can be prevented or reduced to help minimise losses and waste in the chain.

The research problem is how to reduce the losses or wastage that are as a result of incidence of pre-harvest and post-harvest defects (mechanical, physiological and pathological defects) in the fresh agri-produce supply chain.

1.4 Research Outline

Research Objective

The objective of this study is to identify bottlenecks and solutions to achieving a higher level of quality controlled logistics that can result in reduced food losses in relation to the context factors in a given fresh agri-produce supply chain

Research question

Main Research Question
What are the critical points at which incidence of major fruit defects can be reduced by having a higher level of quality controlled logistics and how does contextual factors influence the level of quality controlled logistics required?

The sub-questions
1. What are the pre-harvest and postharvest factors that influence incidence of mechanical and physiological defects fruit defects in tropical fruit?
2. Which are the most critical points at which incidence of mechanical and physiological defects fruit defects should be reduced or prevented?
3. Which quality and logistics activities are important to prevent or reduce incidence of mechanical and physiological defects in the supply chain?
4. What are the bottlenecks to achieving a higher level of quality and logistics control in fresh agri-produce supply chain?
5. How do contextual factors influence the level of quality controlled logistics in fresh agri-produce supply chains?

Hypothesis

The assumption in this study is that identifying factors influencing incidence of fruit defects and having information on fruit quality as precisely as possible at specific points in the chain can help achieve a higher level of quality control and quality control and be able to direct the fruits to reach the consumer at the same quality level as at the beginning of the chain, minimising losses and waste that are due to defects. The hypothesis is that;

Lack of quality control and insufficient logistics control at identified critical control points contributes to high food losses especially in complex supply chain.

It is important to mention that part of the literature review focus on the Kiwi fruit and later on cases studies were done in the banana fruit and cut flower supply chain. the reason for the was that the initial plan when this study began was to evaluate the model developed in the kiwi fruit supply chain in New Zealand, However, there were some changes when the study had already began and we ended up conducting the case studies in banana fruit and cut flower supply chain. Hence, mismatch between so literature in the literature review section and case studies used.

1.5 Research Plan

This thesis is divided into 7 chapters and content in each chapter is described below.

Chapter 1: This chapter introduces the problem situation and a background of the problem is given. Research objective, research questions and the hypothesis are all discussed in this chapter.

Chapter 2: This chapter is meant to give a deep insight into the problem situation and to provide literature that can be used to address the problem. Literature on factors influencing incidence of tropical fruit defects, literature of logistics control, quality control and literature on quality controlled logistics concept is present.

Chapter 3: A conceptual model is developed in this chapter and this model developed from literature analysis done in Chapter 2. Also presented in this chapter is the Quality Controlled Logistics Model that is developed from the conceptual model. Elements of the research model are discussed and indicators of the research model are also presented.

Chapter 4: Two case studies conducted in this study are presented in this chapter. The methodology used to collect the data is also presented. Results of the assessment of level of quality controlled logistics in the supply chains studied are presented in this chapter. The chapter ends with a discussion of the results.

Chapter 5: In this chapter the Quality Controlled Logistics Model developed in this study is evaluated. Areas of possible improvement of the model are discussed. The hypothesis used in this study is also evaluated.

Chapter 6: Bottlenecks and alternative solutions to achieving a higher level of quality controlled logistics are discussed in this chapter.

Chapter 7: This is the last chapter and evaluation of the way the research was conducted is discussed.

CHAPTER 2 THEORY ANALYSIS

In this chapter, the techno-managerial analysis developed by Luning and Marcelis (2006) will be used to explain different theories from food technology and management science that can be used to analyse pre-harvest and postharvest factors that influence incidence of fruit defects in the kiwifruit supply chain. Theory of the relationship between pre-harvest factors and postharvest fruit defects, critical points at which incidence of major fruit defects are high are identified, and also quality activities and logistics activities to reduce the defects are analysed in this chapter.

2.1 Quality properties of tropical fruits

From a consumer perspective, major quality attributes of fruit include appearance, texture, flavour and nutritive value and safety (Reid, 2002). However, growers choose a cultivar that scores high on characteristics such as yield, disease resistance, ease of harvest, and transportation quality. As for distributors and retailers, appearances together with firmness are important quality attributes, and they are concerned about the time-temperature profile during storage in order to keep the level of those attributes sufficiently high. Finally, colour, texture, taste and flavour are the most important attributes for consumers (Aked, 2002). Therefore, it is necessary to evaluate the characteristics of the product in order to meet the expectations of all actors in the chain.

Appearance is the key factor for consumers in making purchases of fresh produce (Aked, 2002). Vital components of visual quality include colour and colour uniformity, texture, glossiness, and absence of defects in shape or skin finish and freedom from disease (Reid, 2002). Many fruits undergo colour changes as part of the ripening process and in some cases fruit colour is a strong indicator of eating quality and shelf life (Kader, 2002). Total flavour can rarely be assessed by the consumer prior to purchase but it is critical in the repeat purchase of a particular product. Key taste components in fresh produce are sweetness, acidity, astringency and bitterness (Reid, 2002). Aked (2002) reported that sweetness of some fruits can increase dramatically during ripening due to starch to sugar conversions. Quality attributes of fresh fruits are presented in Table 3 (Aked, 2002, Reid, 2002, Kader, 2002, Huyskens-Keil and Schreiner, 2004).

Table 3: Quality components of fresh fruits and vegetables

Main factors	Components
Appearance	*Size*: dimensions, weight, volume *Shape*: diameter/depth, ratio, smoothness, compactness, uniformity *Colour*: uniformity, intensity *Gloss*: nature of surface wax *Defects*: external, internal, morpho1ogical, physical and mechanical, physiological, entomological
Texture	Firmness, hardness, softness, elasticity Crispness Succulence, juiciness Mealiness, grittiness Toughness, fibrousnesses
Flavour	Sweetness, Sourness (acidity), Astringency, Bitterness Aroma (volatile compounds) and Off-flavours and off-odours
Nutritive value	Carbohydrates (including dietary fibres) Proteins, Lipids, Vitamins and Minerals
Safety	Naturally occurring toxicants, Contaminants (chemical residues, heavy metals), Mycotoxins and Microbial contamination

An understanding of the quality attributes of tropical is important in this research as it gives the ideal fruit quality that is expected by the customer and also a benchmark of the quality level that should be maintained throughout the supply chain. The literature is valid and reliable as the quality attributes mentioned can be used as indicators that help to identify points where fruit quality deviated from the expected quality.

2.2 Types of defects in tropical fruits supply chain

Fruit defects can be divided into six main categories (Lopez Camelo, 2004, Martinez-Romero et al., 2004); (1) morphological defects caused by sprouting, rooting, curvature and seed germination, (2) physical defects such as shrivelling and wilting, (3) mechanical damage which includes punctures, cuts, deep scratches, splitting, skin abrasions and scuffing, deformation, and bruising, (4) physiological defects such temperature–related disorders that include freezing, chilling, sunburn, sunscald, and internal breakdown of fruit tissue, (5) pathological defects due to fungi, bacteria and viruses, and (6) Insects and chemical defects. However, physiological and mechanical defects are the dominant defects of kiwifruit (Feng et al., 2006) and more emphasis is given to these two defects in this study. This is also supported by Martinez-romero et al (2004) reported that the most dominant causes of fruit damage during pre-harvest are physiological damage and mechanical damage.

a) Mechanical damage

Mechanical damage is a type of stress that occurs during the postharvest manipulation of fruits (Martinez-Romero et al., 2004). Martinez-romero et al (2004) further reported that mechanical damage of fruits is mainly as a consequence of inappropriate harvest, manipulation and transport techniques and is one of the most common and severe defects. Lopez Camelo (2004) reported the most visible symptoms of mechanical damage are bruises and they are the major cause of fruit rejection. Bruise is defined as a damage of fruit tissue as a result of external forces, which cause physical changes of texture and or chemical changes of colour, smell and taste.

According Martinez-romero et al (2004) mechanical injuries can be externally visible and easily detectable or non-externally visible because internal bruising is masked by external colour. There are three main forms of bruises (Bollen et al., 1995).

i. Impact: Injury caused either by dropping the fruit or packed fruits onto a hard surface or the impact of fruit rubbing against other fruit. These types of bruises are common during harvest and packing.
ii. Compression: Deformation under excessive pressure. This often occurs during storage and bulk transportation and is caused by the weight of the mass of fruits on bottom layers. It also happens when the packed mass exceeds the volume of the container or by the collapse of weak boxes or packages unable to withstand the weight of those piled up high.
iii. Abrasion: Superficial damage produced by friction of other fruits, packaging materials, or packing belts.

According to Timm et al (1998) there are two major causes of mechanical damage for fruit during postharvest handling, excessive impacts during harvesting, grading, handling, and transportation, and excessive compressive forces during package handling. Impact and compression bruises normally occur during the post-harvest stage and are as a result of rough handling in the chain (Martinez-Romero et al., 2004). During the pre-harvest stages, mechanical damage such as bruises, abrasions, cuts, and punctures are common.

b) Physiological disorders

Physiological disorders result from metabolic disturbances caused by internal and external factors such as nutritional imbalance and temperature and surrounding atmosphere respectively (Mishra and Gamage, 2007). Martinez-romero et al (2004) defined physiological defects as those defects caused due to changes in internal fruit structure or internal breakdown of the fruit. Examples of physiological disorders include; freezing Injury, chilling injury, physiological pitting and internal breakdown. Some physiological disorders such as chilling injury and internal breakdown develop as a direct consequence of postharvest handling practices, while some such as fruit softening, develop after harvest as a consequence of pre-harvest causes such as a disruption in normal water relations in fruit tissues, deficiency of nutrient elements, or the effect of the chemicals applied in the field (Ladaniya, 2008). Major pre-harvest factors that influence the incidence of postharvest disorders are nutritional status of produce, level of maturity at harvest and temperature (Mishra and Gamage, 2007). Other pre-harvest factors include type of the produce, variety and soil type (Mishra and Gamage, 2007).

2.3 Factors influencing incidence of fruit defects during pre-harvest stage

Fruits defects can be induced in several ways while the fruit is still on the plant or in the orchard. According to Kays (1999) fresh fruits are prone to physiological defects, mechanical defects and pathological defects whilst in the orchard. Pre-harvest defects of tropical and subtropical fruits can be categorized based on the cause of the condition into the following classes (Martinez-Romero et al., 2004): (1) biological factors (pathological, entomological, animal), (2) physiological factors (physiological disorders, nutritional imbalances, maturity), (3) environmental/cultural factors (climate, weather, soils, water relation), (4) mechanical damage, and (5) genetic variation.

Biological factors causing defects

a) *Pathological damage*
Plant pathogens cause substantial losses of fruits during production (Kays, 1999). The skin of a fruit is normally an effective barrier against most potentially invading bacteria and fungi causing rotting of tissue (Kays, 1999). Any rupture of this barrier caused by damage or injury to the skin will provide an inlet for infection and will also stimulate physiological deterioration and dehydration (Martinez-Romero et al., 2004). The stress imposed by plant pathogens leads to distinct alterations in the appearance of the affected tissue.

The kiwifruit is affected by the fungus *Botryosphaerea dothidea* as early as during cultivation. The infestation is manifested externally by a small brown area on the skin (Kirkby et al., 2004). Other pathogens such as *Botrytis cinerea,* which causes stem-end rot in kiwifruit also, have considerable effects on the storage behaviour of kiwifruit. *Botrytis cinerea* can directly invade the fruit or enter through wounds (Crisosto et al., 2005). Maintaining kiwifruit firmness by cold storage and use of controlled atmospheres can significantly reduce pathological breakdown (Kirkby et al., 2004).

b) *Insect injury*

Feeding by a diverse range of insects results in distinctly undesirable alterations in fruits (Kays, 1999). Growth malformations, russetting, scars and are common symptoms of insect damage (Beattie and Wade, 1998). In kiwifruit, scale (greedy, latania, oleander) insects can be a problem if populations build up too extensively as they can attack the fruit causing premature softening during storage. The omnivorous leaf roller (*Platynota stultano*) is another insect that cause damage in kiwifruit. It feeds primarily on leaf tips and growing tips, and damages fruit by scarring its surface. In East Africa and West Africa, fruit flies are a major cause of mango fruit damage. In Benin, over 70% of the total production was lost due to fruit flies in 2005, 2006 and 2007 (Vayssières et al., 2009).

Physiological factors

Nutrient imbalance is a major physiological factor that influence incidence of physiological defects such as calcium injury (Sfakiotakis et al., 2005). Calcium is the nutrient most commonly associated with postharvest disorders of kiwifruits and other fruits such as mango, apple and pear (Ferguson et al., 1999). Chilling injury incidences have been associated with low levels of calcium content (Sfakiotakis et al., 2005). In studies by Sfakiotakis et al (2005), low levels of fruit calcium at early harvest maturities were associated with higher levels of chilling injury, while substantially less chilling injury incidence was recorded in fruit that received pre-harvest $CaCl_2$ sprays. These findings are supported by Lurie (2009) who attributed storage disorders such peel pitting and chilling injury in kiwifruit to suboptimum levels of calcium.

Hewett et al (1999) reported that kiwifruit with low concentration of calcium are likely to develop bruises or water soaked patches during storage, making them more susceptible to mechanical damage. Calcium has been reported to maintain membrane function and better fruit cell wall integrity Ferguson et al (1999) and Sfakiotakis et al (2005) reported that high levels of calcium content help to sustain greater fruit cell wall integrity and membrane permeability.

The main reason for the development of calcium deficiency symptoms in harvested products is because of the way that calcium is transported around the plant (in the xylem only and not the phloem) and the time at which it is available to be imported into fruit, only early in the development and not during maturation (Hewett, 2006).

Environmental factors

Environmental factors can cause mechanical injury whilst fruits are still on the plant (Kays, 1999). Environmental factors that include wind, hail and compression of developing fruit due to adjacent fruit cause mechanical damage in fruits during the pre-harvest stage (Kays, 1999). Types of mechanical injury induced include friction, impact and compression and these lead to one or more types of tissue failure such as, cleavage, slip, and bruising, which result in pronounced alterations in the appearance of the fruit (Hewett, 2006).

Fluctuations in water content of soil, abrupt heavy irrigation or a sudden heavy downpour of rain can also cause fruit splitting (Lurie, 2009). This is supported by Jiang et al (2002) who reported that heavy rain or sudden uptake of water during the last stage of longan fruits development make the pulp expand at a faster rate than the skin, resulting in skin rupture.

Genetic variation

The cultivar is the first and main factor influencing development of physiological disorders in tropical and subtropical fruits (Benitez et al., 2004). In kiwifruit, Hort16A fruit are softer than Hayward at commercial maturity and more vulnerable to mechanical damage (Kirkby et al., 2004) The influence of genetic variation is also reported in peaches and nectarines where susceptibility to chilling injury is also in influenced by genotype. (Lurie and Crisosto, 2005) reported that there is a large variation among different cultivars of peaches and nectarines their susceptibility to chilling injury when stored at either 0 or 5 ◦C.

The selected literature is valid as it details the different factors that can cause fruit defects whilst the fruit is still in the orchard. Also, respective defects caused by the given factors are explained. The selected literature is relevant in that an understanding of these pre-harvest factors is important in identifying the major factors and mechanisms through which fruit defects are induced. An understanding of the pre-harvest factors causing fruit defects makes it easy to institute quality control and logistic control activities that reduce incidences of fruit defects.

2.4 Factors influencing incidence of tropical fruit defects during harvesting stage

Improper harvesting and handling cause extensive fruit injuries resulting in immediate decreases in percentages of fresh fruit available for marketing and it also cause increase in decay during storage or transit (Ladaniya, 2008). Mechanical damage is the prominent cause of fruit defects during the harvesting stage (Ladaniya, 2008). (Crisosto and Kader, 1999) reported that there are three types of damage which can occur during harvest and transport: impact bruising, compression bruising, and abrasion or vibration bruising. Impact bruising is the result of dropping fruits and compression bruising occurs when bins are overfilled and when fruit bump against each other. Abrasion bruising results from fruit rubbing against each other or against container surfaces.

Method of harvesting

Ladaniya (2008) reported that the main factor affecting the sensitivity of fruits to mechanical damage is the harvesting system. The impact of mechanical damage is different depending on whether picking is done manually or mechanically (Martinez-Romero et al., 2004).

a) *Manual harvesting*

Compression and impact forces on fruit associated with manual harvesting and handling have been found to have significant negative effects on fruit quality during storage (Martinez-Romero et al., 2004). Kiwifruit of all firmnesses can be damaged at harvest although softer fruit is more susceptible to mechanical damage (Kader, 1999). During hand-harvesting operations, the picker is normally the greatest potential cause of bruise damage and this damage can be due to amount of pressure applied, length of cutting zone, for example, long stems can injure other fruits, during depositing of fruits inside buckets and during unloading (Martinez-Romero et al., 2004). Bruising, stem-end tears, scratching, and pitting of fruit are common injuries as a result of poor human handling during harvesting (Ladaniya, 2008). During fruit picking, if the fruit does not detach easily from the plant it can be injured by the force of the hand (Beattie and Wade, 1998). This is particularly true when two or three fingertips are used to pull the fruits (Beattie and Wade, 1998). Longer pedicels (10–40 mm) left on fruits, particularly during clipping (Ladaniya, 2008).

b) *Mechanical harvesting*

With the increasing use of mechanical equipment in harvesting of fruits, the mechanical injury on fruits has become a very important problem (Lee et al., 2005). Parts of harvesting equipment can cause bruising due to impact, abrasion and puncture damage during harvest (Lurie, 2009).

Maturity at harvest

The susceptibility of fruits to suffer harvesting injuries due to human handling and harvesting equipment is influenced by the maturity stage at harvest (Martinez-Romero et al., 2004). Maturity stage at harvest affects the kiwifruit's response to the mechanical injury (Martinez-Romero et al., 2004)) and also has an influence of development of physiological disorders later during the postharvest stage (Clark et al., 2004). In general, mature and soft fruits are more susceptible to mechanical injury during harvesting (Lee et al., 2005).

Environmental conditions

Mechanical injury during harvesting of tropical and subtropical fruits is also influenced by the environmental conditions (Knee and Miller, 2002). Irrigation of fruit trees before harvesting and high relative humidity can increase the susceptibility to mechanical injury (Martinez-Romero et al., 2004). For example, in citrus fruits, when the relative humidity is extremely high after rain, sprinkling or fog, just the action of the picker pressing the fruit is enough to induce a specific type of injury, called oleocellosis (Martinez-Romero et al., 2004).

The selected literature is relevant as it details factors that cause tropical and subtropical fruit defects during harvesting. The literature presented give an insight on factors that need to be controlled or closely monitored in order to reduce fruit defects that occur during harvesting. The literature is valid and reliable as it was extracted from published scientific journals and books.

2.5 Factors influencing postharvest incidence of fruit defects during postharvest phase

Postharvest defects in tropical and subtropical fruits have great economic repercussions, mainly due to negative changes in organoleptic attributes such as skin and flesh browning and off-flavours, and internal breakdown reactions (Martinez-Romero et al., 2004). Fresh fruits pass through several stages from the orchard to the industry, before reaching consumers and at each of these stages, mechanical and physiological damage can be induced (Martinez-Romero et al., 2004). Stages at which tropical and subtropical fruits are damaged and the respective causes during the postharvest phase are discussed below.

Sorting and packaging

After harvesting, fruits may pass through several containers and every time there is a change of container there is the possibility of bruises due to impacts damage from other fruits, containers and equipment used to sort and pack the fruit (Knee and Miller, 2002). Zeebroeck van et al (2007) reported that in fresh fruits, packaging, sorting and grading are the main stages where impact damage is dominant. Mechanical damage in the form of impact damage is the dominant kiwifruit defect during this sorting and packing stage. During sorting and grading, impact bruise injury occurs by fruit-fruit or fruit-to-hard surface contact when fruit are dropped or bounced (Beattie and Wade, 1998).

i. *Sorting/grading*

During grading, the most common damage symptoms are superficial lesions caused by close contact with metallic parts, and impacts that take place in the transfer areas of washing, treating, sorting and sizing (Benitez et al., 2004). Dropping packages and impact shocks during grading also cause impact bruising (Wills et al., 1998).

ii. *Packaging*

Packaging lines with several transfer points with high drop height at these transfer points can cause impact bruise (Beattie and Wade, 1998). Abrasion injury also occurs when fruits rub together when moving on a conveyer during sorting (Knee and Miller, 2002). Cushioning the hard surfaces on equipment and controlling the roll velocity of each item conveyer belts or packaging line to a low but adequate speed, can help reduce impact bruising (Martinez-Romero et al., 2004). Use of foam nets during fruit packaging can reduce damage to individual fruit (Knee and Miller, 2002). Compression bruising can occur during packaging due to pressure of overlying fruit in a stack, or the pressure applied by walls or lids of packages or bins (Beattie and Wade, 1998). Under-filling and over-filling should be avoided so that individual fruits are held firmly, but not too tightly, within the package to avoid impact damage from free moving fruits and compression damage due to pressure of overlying fruits, respectively.

Storage

During storage of fresh fruit including kiwifruit, time-temperature conditions are a critical factor influencing postharvest fruit defects. Temperature is the most important environmental factor that influences the deterioration of harvested commodities (Kader, 1999). Physiological defects are the dominant type of fruit defect that occurs during fruit storage and time-temperature condition is the main factor influencing these physiological defects. Temperature also has an influence of kiwifruit deterioration by inducing heat damage, chilling and freezing damage (Crisosto, 2008).

Most tropical fruits have an optimal shelf-life at temperatures of approximately 0 ^{0}C (Kader and Rolle, 2004). The rate of deterioration of perishables increases two to three-fold with every 10 ^{0}C increase in temperature (Kader and Rolle, 2004). For example, (Stow et al., 2004) found that in cherries, cold fruit (0 ^{0}C) were more sensitive to impact damage than warmer fruit (5 ^{0}C). This is due to the physical properties of cell walls that are affected by temperature, as stiffness is greater at lower temperatures and cell walls are less flexible and more susceptible to pressure damage (Lurie, 2009). Effect of temperature on tropical and subtropical fruits is shown in Table 4 (Kader, 1999).

Table 4: Effect of temperature on chilling-sensitive fruit

Temperature (^{0}C)	Effect on produce
30 – 35+	High – temperature injury
15 – 25	Optimum ripening range
8 – 14	Optimum for storage and transport
0 – 14	Chilling injury
<0	freezing injury

i. *Heat injury*

High temperature conditions are injurious to tropical and subtropical fruits (Beattie and Wade, 1998). Organs removed from the plant lack the protective effects of transpiration and direct sources of heat such as sunlight, can rapidly elevate the temperature of tissues to above the thermal death point of their cells, leading to localized bleaching, necrosis (sunburn or sunscald) or collapse of the fruit tissues (Kader and Rolle, 2004). Temperatures either above or below the optimal range for kiwifruit can cause fruit defects due to the following disorders:

ii) *Freezing injury*

The freezing point of tropical and sub-tropical fruit tissues in relatively high, ranging from -3 ^{0}C to -0.5 ^{0}C, and disruption caused by freezing results in immediate collapse of their tissues and a total loss of cellular integrity (Korsten, 2006). All fruits are liable to injury if their tissues begin to freeze (Korsten, 2006). Freezing injury results in discoloration of kiwifruit (Korsten, 2006). Freezing occurs in cold storage systems either due to inadequate refrigerator design, or to thermostat failure (Kader and Rolle, 2004). Freezing can also occur upon exposure to inclement weather conditions as when produce is allowed to remain for even short periods of time on unprotected transportation docks during winter (Kader and Rolle, 2004). The resultant tissue injury from freezing injury becomes visible when the frozen tissue thaws, and the extent of injury depends on the rate of thawing (Beattie and Wade, 1998). After thawing, freeze injured tissue is typically darker and exhibits a flaccid, water soaked appearance (Kays, 1999).

iii) *Chilling injury*

Tropical and subtropical fruits respond unfavourably to storage at low temperatures which are well above their freezing point but below a critical temperature termed their chilling threshold temperature or lowest safe temperature (Kader and Rolle, 2004). Chilling injury is a temperature-associated physiological disorder which a product develops when exposed to low temperatures (Lurie, 2009) and is a result of the time-temperature relationship (Ladaniya, 2008). Chilling is different than freezing in that there is no hardening or ice crystals in the tissues in former, though there can be some resemblance in symptom development (Ladaniya, 2008). Chilling injury generally requires an extended exposure and the symptoms often do not appear until after the product is returned to non-chilling temperatures (Kays, 1999).

Chilling injury causes significant losses in GOLD kiwifruit (*Actinidia chinensis* 'Hort16A') (Burdon et al., 2007). Kiwifruit stored at 0 ^{0}C for more than 6-8 weeks normally succumb to chilling injury (Maguire et al., 2004). Incidence of chilling injury in kiwifruit is greater during longer storage duration for kiwifruit harvested at early maturity at storage temperature of stored at 1.5 ^{0}C (Sfakiotakis et al., 2005). Symptoms of chilling injury manifest as a ring or zone of granular, water-soaked tissue in the outer pericarp at the blossom end of the fruit (Maguire et al., 2004). Chilling injury causes the release of metabolites, such as amino acids and sugars, and mineral salts from cells that together with the degradation of cell structure provide an excellent substrate for the growth of pathogenic organism, especially fungi (Lurie, 2009). As a result, increased rotting is a common occurrence in tropical and subtropical fresh fruit at low temperature storage (Wills et al., 1998). However, some manipulations can be used to delay the onset of chilling injury symptoms and these are discussed below.

Intermittent warming

Intermittent warming involves placing the fruit immediately in cold storage, but removing them to 20 ^{0}C for a day every 10 to 14 days (Lurie and Crisosto, 2005). Temperature manipulations can also affect the performance of kiwifruits during storage. Intermittent warming has also been found to delay chilling injury in kiwifruits. The use of warmer temperature conditioning to reduce chilling injury has also been successfully applied to 'Hass' avocados (Woolf et al., 2003).

Controlled delayed cooling

Delayed storage involves holding the fruit in warm conditions for 1 or 2 days after harvest before placing them in 0 ^{0}C storage (Lurie and Crisosto, 2005). Delayed storage at an elevated temperature can reduced the level of chilling injury in kiwifruit. Storage at 3 ^{0}C prior to cold storage at 1.5 ^{0}C was found to be effective at reducing the risk of chill related disorders (Sfakiotakis et al., 2005). This phenomenon had also been previously observed by Lallu (1997) who reported that incidence and severity of symptoms of chilling injury in kiwifruit was significantly reduced by delays at ambient conditions prior to cool storage.

Transportation

Many of the losses that occur during transportation are due to inappropriate packaging and box arrangement inside the lorries (Beattie and Wade, 1998). Mechanical damage is the dominant type of fruit defect that occurs during this transportation stage and the common forms of mechanical damage during this stage are impact damage due to dropping of boxes, compression damage due to high stacking and overfilling of packs, and vibration damage due to poor stacking methods (Beattie and Wade, 1998). Example of the extent of losses is reported in Acıcan et al (2007) where total loss in tropical and subtropical fruits during transportation to the market in Turkey is reported to be 25% on average. In a transportation test done by Acıcan et al (2007) using apple cultivar Golden Delicious, damage rates of apples ranged between 45.09% and 45.11% for those placed into crates reinforced with cardboard at the base, and directly stacked into the crates, respectively.

a) *Vibration injury*

During transportation, fruits are most likely to suffer vibration injury, a series of small but possibly cumulative loads applied to the fruit that cause abrasion or bruising (Beattie and Wade, 1998). Vibration injury is common during transport, resulting in abrasion marks and cuts ranging from light rubbing to removal of the skin and possibly some of the flesh (Wills et al., 1998). In fruits packaged in stacks during road transport, vibration injury can be induced by vibrations resulting from the interaction of the road surface and the vehicle suspension system if the stacks are not properly arranged (Wills et al., 1998). Although packaging is supposed to protect fruits from mechanical damage during transportation and handling, the degree to which vibration influences fruit quality is dependent on the type of packaging (Lallu et al., 1999).

b) *Compression injury*

During transportation, compression injury can also occur due to overfilling of containers as fruits in the bottom of the container are subject to compression from other fruits above (Chonhenchob and Singh, 2003). Symptoms of compression injury include bruises, cracks, splits, and deformation. Other factors inducing compression injury include poor hauling of the trailer which allows packages inside to sway and packages stacked too high, the movement produced within a particular box increases in relation to its height in the stack (Martinez-Romero et al., 2004).

The choice of container system and packing configuration in the container can greatly affect the bruising of fruits during shipping and handling (Chonhenchob and Singh, 2003). In kiwifruits, Lallu et al (1999) reported that packaging influence the type, incidence and severity of damage caused by vibration in packed kiwifruit. Packages are best handled as unit loads on pallets or slip sheets as unit loads are much less vulnerable to mechanical damage than individual packages (Beattie and Wade, 1998). Correct packaging can help prevent mechanical damage to fruit during transport and distribution. Under-filling and over-filling should be avoided so that individual fruits are held firmly, but not too tightly, within the package (Timm et al., 1996).

The way fruit batches are stacked also has an influence on both incidence of compression damage and physiological disorders. Tanner et al (2003) reported that batches must be stacked is a way that enable proper air circulation, in order to facilitate removal of heat from the produce as well as to dissipate incoming heat from the atmosphere temperatures Also, batches should not be stacked so densely that cold air circulation is blocked or so high that it is out of the refrigerated zone and becomes exposed to ambient air temperatures (Tanner and Amos, 2003).

Presented literature is relevant as it help to understand postharvest fruit defects and their causes at each stage of kiwifruit supply chain. The literature is valid as it details specific causes of fruit defects at each stage of the fruit chain. This information is important in establishing critical quality points within the tropical and subtropical fruit supply chain. The selected literature is from published scientific journals and article which makes it credible to use in this study.

2.6 Pre-harvest factors influencing incidence of postharvest defects

According to (Ladaniya, 2008) some physiological disorders such as freezing and heat injury develop as a direct consequence of postharvest handling practices, while some such as fruit softening and susceptibility to chilling injury develop during the postharvest stage as a consequence of pre-harvest causes such as a disruption in normal water relations in fruit tissues, balance of nutrient elements or fruit maturing at harvesting. Major pre-harvest factors that influence the incidence of postharvest disorders such as chilling injury and physiological pitting in kiwifruit are nutritional status, level of maturity and temperature (Mishra and Gamage, 2007). Fonseca (2009) reported that there are few postharvest disorders of fruits that are not affected by pre-harvest factors. This is supported by earlier reports by Ferguson et al (1999) who reported that development of disorders during postharvest ripening and storage of fruit is mainly depends on pre-harvest factors that include maturity of fruit at harvest, field temperature history and nutritional availability.

Knowledge on relationship between pre-harvest factors and postharvest defects can provide the means to anticipate hidden potential defects and can be used to appropriately handle products at high risk (Kirkby et al., 2004). This is also supported by (Lurie and Crisosto (2005) who reported that identification of pre-harvest factors that have an influence on incidence of postharvest defects, raises the possibility of producing fruits that are less prone to postharvest disorders such as chilling injury. Understanding the relationship between pre-harvest factors and postharvest disorders is therefore important in developing practices that prevent or reduce incidence of fruit defects. For example, to develop strategies for preventing incidence of the postharvest disorder, chilling injury, it is necessary to define its relationship with pre-harvest field temperature (Cooper et al., 2007).

Kirkby et al (2004) reported understanding the influence of pre-harvest factors on development of postharvest disorders can lead to early identification of fruits that are likely to be susceptible to such disorders during storage and consequently, help prevent development of post-harvest defects. Pre-harvest factors such as maturity and field temperature influence the response of kiwifruit to chilling temperatures (Maguire et al., 2004). This was also confirmed by Burdon et al (2007) who reported that susceptibility of kiwifruit to chilling injury is dependent on field temperature, maturity of the fruit at harvest and also fruit composition at harvest.

Pre-harvest temperature

Postharvest responses of fruit to chilling stress are often influenced by pre-harvest field temperatures (Fonseca, 2009). In the studies done by Burdon et al (2007), on 'Tomua' kiwifruit, the incidence of chilling injury was related to the ambient temperatures before harvest. Burdon et al (2007)reported a distinct decrease in chilling injury incidence that corresponded with a week of colder weather before the fifth harvest during their field studies. Burdon et al (2007)) attributed this to the possibility of temperature acclimation before storage. In other fresh fruit such as apple, pre-harvest acclimation by low ambient temperatures has been linked to the reduced susceptibility of fruit to scald development in storage. In their study on pre-harvest factors influencing postharvest disorders in apples and avocado fruits, Ferguson et al (1999) reported that high temperatures experienced by fruits on the tree have an influence on the response of the fruits to low and high postharvest temperatures. Information on pre-harvest temperature conditions can therefore be used to anticipate and prevent development of postharvest disorders such as chilling injury in kiwifruit during postharvest storage.

Maturity at harvest

Maguire et al (2004) investigated the influence of maturity on chilling injury and physiological pit disorder in kiwifruits and reported that physiological pit was greater after longer storage time for fruit harvested when more mature and stored at 1.5 ^{0}C. Incidence of chilling injury was higher in early mature harvested kiwifruit stored at 1.5 ^{0}C. From their study, Maguire et al (2004)concluded that maturity of kiwi fruit at harvest is a key indicator of the risk of fruit developing chill-related disorders as there is higher risk of physiological pit disorder in more mature kiwifruit and chilling injury in less mature kiwifruit.

Findings by Maguire et al (2004) are consistent with findings by Clark et al (2004) who reported that kiwifruit picked either too early or too late in its season are more susceptible to physiological disorders such as chilling injury and physiological pit and have a shorter shelf life than fruit picked at the proper maturity stage. In studies conducted by Sfakiotakis et al (2005), early harvested fruit were found to be more susceptible to chilling injury than the mid or late harvested fruit. Sfakiotakis et al (2005) attributed this to a lack of a cold acclimation period. Physiological pit in kiwifruit is also associated with maturity at harvest. Sfakiotakis et al (2005) further reported a higher incidence of physiological pit during long storage duration of more mature kiwifruit compared to fruit harvested at early maturity. The higher risk of physiological pit in more mature fruit and chilling injury in less mature fruit narrows the optimal harvest window for fruit. Effectively managing maturity at harvest is therefore essential to obtain optimum storage potential and to minimise kiwifruit loss during storage (Sfakiotakis et al., 2005).

The increased susceptibility to chilling injury by immature kiwifruit reported by Maguire et al (2004) and Sfakiotakis et al (2005) is consistent with earlier findings on susceptibility to chilling injury in mango studies done by Mohammed and Brecht (2002). Mohammed and Brecht (2002) reported that successful storage of mangoes ‘Tommy Atkins’ at chilling temperatures is related to physiological maturity. Besides chilling injury, storage life of kiwifruit is also limited by excessive fruit softening which is influenced by harvest maturity of the kiwifruit (Burdon et al., 2007). Feng et al (2006) reported that kiwifruit batches harvested early at less mature stage softens at faster rates than kiwifruit batches harvested late at advanced maturity.

Nutritional factors

Pre-harvest nutritional factors such as calcium deficiency influence the development of postharvest disorders in tropical and subtropical fruits (Beattie and Wade, 1998). Hewett (2006) reported that pre-harvest calcium deficiency of kiwifruit is linked with subsequent postharvest quality and disorders. For example, calcium deficiency results in development of physiological pit in kiwifruit (Kirkby et al., 2004). Stepwise discriminant analysis carried out by Feng et al (2006) on four softening-rate groups of kiwi, indicated that fruit ratio of calcium and nitrogen have significant roles in development of physiological pitting. Feng et al (2006) reported that kiwifruit batches harvested late at advanced maturity with high calcium to nitrogen ratio are likely to soften slowly with less incidence of physiological pitting disorder.

Calcium deficiency which results in physiological pitting in kiwifruit is normally overcome by spraying with calcium salts during fruit development or by postharvest calcium dip or drench treatments of the fruit (Hewett, 2006). Sfakiotakis et al (2005) also reported pre-harvest $CaCl_2$ sprays can help reduce susceptibility to chilling injury in kiwifruit.

Fruit composition at harvest

In the studies done by Burdon et al (2007), on 'Tomua' kiwifruit, the incidence of chilling injury was reported related to the composition of the fruit at harvest. More mature kiwifruit has a high content of soluble solids concentration (SSC) and Burdon et al (2007) reported that kiwifruit with high soluble solids concentration are more firm and less susceptible to chilling injury. This is consistent with earlier reports by Mitchell and Kader (1998) who reported that chilling injury pattern normally relate to the pattern of soluble solids content of the fruit. This is because fruit with low soluble solids concentration freeze at a higher temperature than fruit with high soluble solids content (Mitchell and Kader, 1998). However, Cooper et al (2007) reported that kiwifruit harvested more mature with more than 9% SSC softened most quickly. Early harvested fruit with or below 5.5% SSC are less susceptible to softening (Cooper et al., 2007).

The presented literature gives an insight on how pre-harvest conditions and factors are related to development of postharvest disorders. The literature is relevant as it provides an insight on how various pre-harvest factors influence incidence of postharvest disorders in the tropical and subtropical fruit supply chain. The presented literature is valid as understanding the relationship between pre-harvest factors and postharvest disorders allows manipulation of pre-harvest conditions or storage conditions to predict and suppress postharvest incidence of fruit disorders. The presented literature is also reliable as it has been extracted from published scientific journal and articles.

2.7 Critical Points for preventing incidence of defects

There is a need to identify the critical points where the incidence of mechanical damage is higher from the point of view of the economic and commercial repercussions (Martinez-Romero et al., 2004). Although fresh agri-procude defects can occur at many stages or points along the supply, potential points where the incidence of defects is highest need to be given careful consideration. These points are key to preventing or minimising incidence defects and it is important to recognise these points, get the appropriate information, and develop strategies to reduce the development of defects at such points.

For this study, a critical point is defined as *a point, step, or procedure at which incidence of mechanical and/or physiological fruit defects is high or have an influence on development of mechanical and/or physiological defects at later stages in the kiwifruit supply chain*. Control activities at this point can help to prevent or reduce development of the defects at that particular point and/or at subsequent stages in the chain.

The concept of critical point used in this study is adapted from the critical control points (CCPs) concept which is an essential element of the hazard analysis critical control point (HACCP) system. HACCP system is implemented to provide assurance of food safety in the food industry (Sperber, 2005). Critical control points (CCPs) have been defined as operations, practices, procedures, or processes, at which control should be exercised to achieve a quantifiable reduction in a hazard, or its stabilization, that leads to an acceptable, safe food product (Notermans et al., 1995). The concept of CCPs is therefore adapted in this study to identify the critical points in the agri-produce supply chains.

Critical control points are normally identified using a CCP decision tree. A decision tree is a logical series of questions that are asked for each hazard. There may be more than one CCP at which control is applied to address a given hazard and in some cases more than one critical limit will be elaborated at a particular step (Codex Alimentarius, 1997). In this study identification of critical control points is important in that it can be used to pin-point pre-harvest and postharvest operations or stages at which quality control and logistics control are essential to prevent or reduce fruit defects.

2.8 Logistics control

Logistics can be defined as, “that part of the supply chain process that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements." (Council of Logistics Management definition of Logistics, 2003, cited in (Van der Vorst et al., 2005). Gustin et al (1994) defined logistics as a system that directs and controls the physical handling of products between the points of raw materials acquisition and finished goods consumption, encompassing a number of overlapping functions or activities.

Logistics planning and management

A logistical system is composed of a number of elements which have to be managed properly in order to deliver final products in the right quantities at the right time and quality at the right place, and at a reasonable cost. This puts challenging requirements on the agri-food chain (Van der Vorst et al., 2005) and there is a need to make the right logistics decisions so as to meet customer expectations. For example, whilst temperature and relative humidity are critical factors affecting fruits quality (Kader, 2002) logistics decisions heavily determine these conditions by defining storage time and time of shipping goods (Luning and Marcelis, 2009).

Logistics planning in agri-foods supply chain involves several levels of hierarchical decisions. Logistics decisions may be divided into several dimensions based on various criteria (Riopel et al., 2005). The common grouping into strategic, tactical and operational levels can be based on one or more of the following criteria associated with the decisions such as, time frame, resource requirements, or level of managerial responsibility (Riopel et al., 2005). These criteria are inter-related, for example, strategic decisions are usually made at high level in the organization and address long-term issues with significant resource implications (Riopel et al., 2005). (Van der Vorst et al., 2005) distinguished the three levels of logistical management as follows;

1. Strategic planning

- Goals, and strategies for attaining the goals are defined
- Competitive decisions are made within multiple planning horizons, usually annually, or over multi-year planning horizons to achieve an enterprise-wide, or chain-wide, optimal solution which reflects global objectives
- These logistical decisions are mainly concerned with the establishment of the supply chain configuration; for example, site selection, capacity determination, process choice and investments in new resources.

2. Tactical planning

- Organisational goals and market performance demands are translated into logistical objectives
- Tactical planning reflects decisions for the coming months
- Decisions, rules and procedures are formulated and responsibilities and authorisation structures are set and also decisions on information to be implemented.
- Suppliers are selected and contacts with customers are made about sales and performance criteria
- Emphasis is on procurement, availability and deployment of people, materials and other resources to meet actual demand.

3. Operational control and management

- Is concerned with daily operations of a facility in response to set objectives to ensure that the most profitable way to fulfil actual order influence the flow of materials and information

- It contains all operational decisions, which day-to-day operations up to two weeks in advance.

Examples of logistic decisions made at each of the three levels of logistical planning in the agri-food chain are presented in Tables 5.

Table 5: Levels of logistics planning and respective decisions in fruit supply chains

Level of logistics planning	**Logistics decisions**	**Reference**
Strategic planning Long - term	• Type of cooperatives and size to form • Supplier selection • Plant location and physical distribution system • Selection of farming technology, financial planning, design of supply networks, and crop rotation strategies.	Zhang and Wilhelm, (2009) Semini et al. (2008) Krishnakumar et al. (2009) Ahumada and Villalobos, (2009)
Tactical planning Mid - term	• Size of an orchard, sections to be planted and varieties to grow • Harvesting schedules • Selecting the market segments to target • Scheduling applications of pesticides • Inventory rules and polices • Production policies and lot sizes • Transportation rules and policies	Zhang and Wilhelm, (2009) Krishnakumar et al. (2009) Semini et al. (2008) Ahumada and Villalobos (2009)
Operational Short - term	• Scheduling of harvesting operations • How to distribute, transport or store produce • Replenishment decisions • Transportation scheduling and mode of transportation	Jang and Klein (2009) Semini et al. (2008) Krishnakumar et al. (2009)

The presented literature is relevant for this study as it helps bring an understanding of different levels of logistics planning in supply chains and possible logistics decisions that can be made at each level in order to reduce fruit defects. The literature is valid and also reliable as it was extracted from published scientific operations research articles.

Integration of logistics activities

Slats et al (1995) stated that integration or interactions between actors in a logistic chain take place at strategic, tactical and operational management levels. The intensity of this interaction is strongest at the operational level as compared with interaction at strategic level. At the strategic level the issues dealt with are focused on development of objectives and policies for the logistic chain. At the tactical level the issues dealt with focus on the means by which the strategic objectives can be realized, such as the tools to use, approaches and resources for logistic chain management. At the operational level the issues dealt with are focused on efficient operation of the logistic chain, such as inventory management, service level and supplier performance (Slats et al., 1995). Boorsma & van Noord (1992) in (Dekker and Van Goor, 2000) defined four forms of integration in supply chain management as; physical integration, information integration, control integration and infrastructure integration.

Physical integration focuses on improving the efficiency of processing the physical flow of products between at least two channel members (Dekker and Van Goor, 2000). These improvements include adjustment and/or standardisation of transportation and material handling equipment, for example containers, and also adjustment and/or standardisation of packages, pallets, roll-containers, crates and the like (Dekker and Van Goor, 2000).

Information integration

Dekker and Van Goor (2000) stated that there is need for a continuous flow of information in the chain and breaking-points in information flows should be prevented. Tools such as Electronic Data Interchange (EDI) can be used to integrate the information flow from primary process to vendors and suppliers (Dekker and Van Goor, 2000). Dekker and Van Goor (2000) reported that for information integration to be a success chain partners must be prepared to share the information that is needed to manage the chain as a single entity.

Control integration is the second form of integration in supply chain management and this is when organisations systematically use information from other forms in the channel to improve processes in order to reducing costs and improving customer service (Dekker and Van Goor, 2000). Control integration focuses on exchanging information to improve the efficiency of information flows and control of processes in the chain. The most intense form of supply chain management is infrastructure integration, where a channel member takes over part of the partner's activities in order to improve processes in the supply chain (Dekker and Van Goor, 2000). Activities are relocated to more efficient and/or more effective places in the channel. A vendor managed inventory (VMI) is an example of infrastructure integration, where the supplier takes over the stock keeping function of the buyer (Dekker and Van Goor, 2000).

The literature on integration of logistics activities is relevant to this study. Integration of logistics activities can help reduce number of handling handing stages in the kiwifruit chain resulting in reduce mechanical defects that are normally due to human handling during loading and unloading.

Inventory management

The request by the consumer for fresh products with elevated quality standard results in the need of a supply chain managed in such way to limit the decay of the product, from the harvest to the point of sale (Busato et al., 2008). There is need for tight control in the supply chain, as well as careful stock management at each stage along the chain (Dada and Thiesse, 2008).

Fresh produce inventory can contain units of different ages, and of concern is the order in which units of each age category are withdrawn from inventory to satisfy demand (Ferguson and Ketzenberg, 2006). This is supported by Dada and Thiesse (2008) who reported that in perishables, the performance of inventory management in the supply chain depends to a large extent on the respective issuing policy that is in place. The purpose of these policies is to determine which products are picked first. Issuing policies that are common in practice are First-In-First-Out (FIFO), Last-In-First-Out (LIFO), or simply issuing in random order (SIRO) (Dada and Thiesse, 2008). The FIFO policy requires that the oldest item within a stockpile to be issued first and the policy is mainly aimed at minimizing stock-outs (Busato et al., 2008). The LIFO policy allows the youngest item on hand to take highest priority (Dada and Thiesse, 2008) and this issuing system is aimed at preventing stock-outs and spoilage (Busato et al., 2008).

The weakness of FIFO and LIFO issuing policies is that both policies are based on the age of the produce, such as the time that a product is retained in storage, regardless of conditions that might render a product unsuitable for distribution (Busato et al., 2008) and that the issuing policies do not consider product quality (Dada and Thiesse, 2008). To circumvent such a weakness, Van der Vorst et al (2007b) suggested that new stock rotation systems can be implemented which are not based on First-In-First-Out (FIFO) or Last-In-First-Out (LIFO), but on First-Expired-First-Out issuing policy.

In their study on sensor applications in the fresh agri-foods supply chain, Dada and Thiesse (2008) distinguished seven different issuing policies that can be used;

1. Sequence In Random Order (SIRO) - Products in the distribution centre are selected randomly and issued to the retailer.
2. First In First Out (FIFO) - Products that have been in the distribution centre longer are selected first.
3. Last In First Out (LIFO) - Products that have been in the distribution centre for the shortest period are selected first.
4. First Expiry First Out (FEFO) - Products in the distribution centre are selected by their age, the items which were manufactured earlier being the first to be issued.
5. Lowest Quality First Out (LQFO) - Products are selected by their quality, the items which have the lowest quality being the first to be issued.
6. Latest Expiry First Out (LEFO) - Products are selected by their age; the items which were manufactured latest are issued first.
7. Highest Quality First Out (HQFO) - Products are selected by their quality; the items which have the highest quality are issued first.

From their studies, Dada and Thiesse (2008) reported that the LEFO and HQFO issue policies recorded the best average qualities. However, these two issuing polices also recorded the highest quality deviations and highest number of spoiled items, which was 25% of all the items. The LIFO issue policy showed better results than LEFO and HQFO. The FIFO, FEFO, and LQFO policies showed the lowest percentage of spoiled items. These results confirms studies done by (Giannakourou and Taoukis, 2003) in which experiments they carried out showed that the amount of rejected fresh food products can be minimised using time-temperature based management system such as FEFO. Dada and Thiesse (2008) further reported that the quality-based LQFO issue policy recorded the least standard deviation of qualities of sold items, which was 4.5% and the least percentage of spoiled items at 2.6%. From these results, Dada and Thiesse (2008) concluded that when the primary objective is to avoid spoilage and to sell items with qualities that vary as little as possible, LQFO is the best issue policy.

The presented literature on inventory management is relevant and valid as the literature gives an overview of different types of issuing polices and advantages and disadvantage of each policy. An understanding of issuing polices that can be used in fresh produce supply chains in important as it gives an idea of the most suitable issuing policy that can be used to prevent incidence of kiwifruit disorders before consumption of the fruit, consequently reducing fruit losses in the supply chains.

Cross-docking

Cross-docking plays an important role in supply chain operations. Due to the need to decrease transportation lead time, shortening the total transfer time at cross-docking is increasingly important (Apte and Viswanathan, 2000). Cross docking is a warehousing strategy that involves movement of material directly from the receiving dock to the shipping dock with a minimum dwell time in between (Apte and Viswanathan, 2000). Wang and Regan (2008) defined cross docking as the movement of material directly from the receiving dock to the shipping dock with a minimum dwell time in between. Unlike in a traditional warehouse where the product moves from receiving to storage to shipping processes, with cross docking, the product moves from receiving to shipping with little or no storage of product at the warehouse (Table 6). The key to cross docking success is to have as short a lead time as possible in the receiving or shipping facility (Wang and Regan, 2008).

Table 6: Key differences between the traditional mixed warehouse and the Cross Docking Warehouse

Traditional Mixed Warehouse	**Cross Docking Warehouse**
Items are put away to storage or order picking areas	Items typically flow in and out the through the and reside in the warehouse for at least more than a warehouse in a single day without being put away to day storage or order picking areas
Items enter the inventory records in the warehouse	Items need not enter the inventory records in the system warehouse
Re-labelling and packaging activity may be carried	May function without any re-labelling or repackaging out in the warehouse

Kurnia and Johnston (2001) reported reduced damaged products as a result of reduced double handling and reduced expired products since warehousing is eliminated as some of the benefits of cross-docking. Wang and Regan (2008) highlighted other benefits of cross-docking such as reduction of order cycle time, which helps improve the flexibility and responsiveness of the distribution network. Cross docking can effectively bring substantial reductions in the transportation cost without increasing the inventories while simultaneously maintaining the level of customer service (Apte and Viswanathan, 2000).

The presented literature on cross-docking is relevant to this study as practicing cross-docking can help reduce lead time and storage time of fruits in warehouses and also reduce double handling. This can effectively reduce development of physiological defects and also reduce mechanical damage that is normally due to fruit handling. The literature is reliable as it was extracted from published sources.

Information and decision making process

Sharing of crucial information is important in decision making and there is need to identify make crucial information when making logistics decisions (Van der Vorst et al., 2005). According to Ferguson and Ketzenberg (2006) sharing of important information between stakeholders can bring about improvements in supply chain performance. Information or data shared within a supply chain is more useful if it is detailed and site-specific giving all actors better information on which to base their logistical decisions (Panagopoulos et al., 2007). The decision making process must satisfy certain preconditions and constraints as described below (De Leeuw, 2002, cited in (Van der Vorst et al., 2005) and summarised in Figure 2;

1. Information about the objectives of control (about what is to be achieved)
2. Information about part of the history and state of the object system (ranging from a single business activity to the complete supply chain) to be controlled

3. Information about available decision alternatives, you have to know what decisions one can or may take. That involves the need to be informed about available facilities and constraints imposed.
4. Information about external variables (what the environment asks from the business process).
5. A model of the object system to be controlled so as to make it possible to derive expected consequences of different decision alternatives and suggesting courses of action depending on weights of objectives.

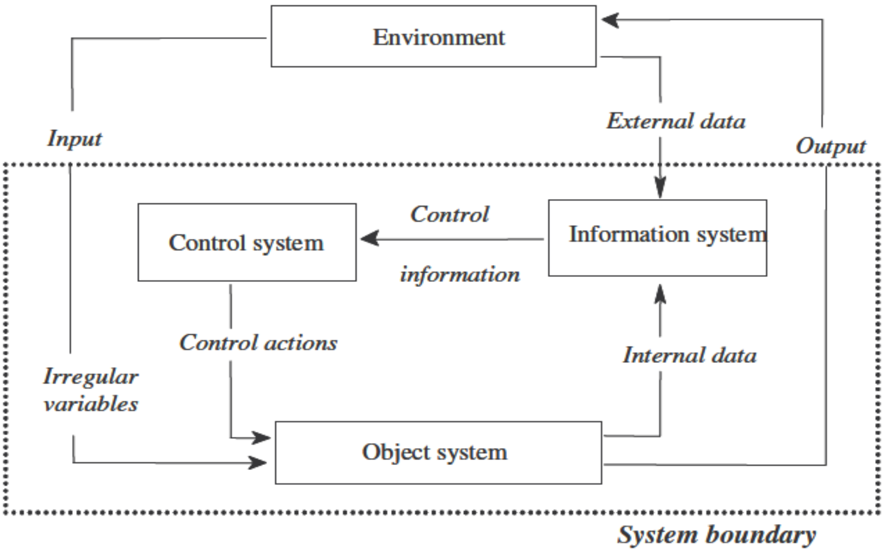


Figure 1: Positioning of the information system (Van der Vorst et al. 2005)

Information sharing and quality of the information shared are two important elements of an information system that are important in this study. According to Simatupang and Sridharan (2004), the starting point of supply chain collaboration is information sharing. Information sharing refers to the extent to which critical information is communicated to one another in the supply chain (Monczka et al., 1998). Information sharing aims to capture and disseminate timely and relevant information to enable decision makers to plan and control supply chain operations (Simatupang and Sridharan, 2004). This is also supported by Whipple et al (2002) who argued that effective information sharing provides a shared basis for concerted actions by different functions across interdependent functions of a firm. Examples of important data that should be shared include points of sale data, demand forecasts, inventory levels, delivery schedules, and inventory costs (Fawcett et al., 2007). Information or data shared within a supply chain is more useful if it is detailed and site-specific giving all actors better information on which to base their logistical decisions (Panagopoulos et al., 2007).

While information sharing is important, the significance of its impact in the supply chain depends on what information is shared, when and how it is shared, and with whom (Jarrell, 1998). Information quality includes aspects such as the accuracy, timeliness, adequacy, and credibility of information exchanged (Monczka et al., 1998). This is also supported by Alvarez (1994) who reported that information shared must be as accurate as possible in order to obtain the best conditions in the supply chain. Jarrell (1998) further reported that sharing information within the entire supply chain can create flexibility, but this requires accurate and timely information.

As such, sharing information of high quality is important in this study as sharing information on measured fruit properties and information of pre-harvest conditions can help predict incidence of fruit defects and corrective action to be taken before the defects develop. Luning and Marcelis (2009) reported that by using time-dependent quality information and quality decay models, it is possible to predict product quality in much more detail, enabling corrective action in the subsequent supply chain processes and to direct specific products batches, under specific environmental conditions to specific market segments. From literature analysis on factors influencing pre-harvest and postharvest in sections 2.5 and 2.6, critical information required for making logistics decisions in the kiwifruit supply chain is summarised in Table 7.

Table 7: Information crucial in making logistics decision in the kiwifruit supply chain

Stage	Crucial information	Reference
Cultivation	• Variety • Field temperature history	Benitez et al. (2004), Lurie and Crisosto (2005), and Lallu, et al (1999)
Harvesting	• Fruit composition • Fruit maturity • Time-temperature conditions	Lee et al (2005), Clark et al (2004) Martinez-Romero et al (2004) Ladaniya (2008)
Sorting & packaging	• Quality status	Beattie and Wade (1998), Knee and Miller (2002), and Martinez-Romero et al (2004)
Storage	• Fruit composition • Maturity at harvest • Time-temperature conditions and relative humidity	Kader and Rolle (2004), Stow et al (2004), Maguire et al (2004), Wills et al (1998), Lallu, et al (1999)
Transportation	• Time-temperature conditions and relative humidity	Kitinoja and Kader (1995), Wills et al (1998), Lallu, et al (1999), and Timm et al (1996)

The presented literature helps to understand the role of information in making quality control and logistics decisions. The literature presented is relevant to this study as precise information on pre-harvest and postharvest conditions and factors can be used to make logistics decisions such as inventory issuing policy and conditions to store or transport fruit batches. The literature is also valid and reliable as it was adapted from published scientific articles.

Supply Chain operations Reference (SCOR) Model

The SCOR model is a business process reference model, which provides a framework that includes SC business processes, metrics, best practices, and technology features (Theeranuphattana and Tang, 2007). According to Robinson and Malhotra (2005), SCOR model defines a supply chain as an integrated processes of ‘plan,’ ‘source,’ ‘make’ and ‘deliver’, and ‘return’ that span the value chain from the supplier’s supplier upstream to the customer’s customer downstream. SCOR-model (Annex G) provides a unique framework that links business process, metrics, best practices and technology features into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chain management and related supply chain improvement activities (Supply Chain Council, 2007). The definitions of the five SCOR supply chain processes are given in Table 8.

Table 8: Definitions of SCOR Processes (Huang et al., 2005, McCormack and Lockamy, 2004)

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

The SCOR model is divided into three standardised levels of process details (Theeranuphattana and Tang, 2007). The top level (level 1) defines the scope and content of the core management processes for the plan, source, deliver and return decision areas. The configuration level (level 2) specifies configuration of the supply chain at the process level by using a tool kit of process categories. At level 2, processes are configured in line with operations strategies. The process element level (level 3) defines a process flow diagram with process elements or specific tasks for each process category in level 2.

The model provides guidance on the types of metrics decision-makers can use to develop a balanced approach towards measuring the performance of an overall supply chain (Hwang et al., 2008). According to Van der Vorst et al (2007a) the SCOR model provides an integrated, heuristic approach for supply chain improvement via (i) the modelling of business processes, (ii) the definition of SCM metrics for evaluating the supply chain and rapidly identifying high value opportunities and (iii) the identification of best practices to provide a candidate list of improvement options. It is important to note that the five processes of the SCOR model can also be linked to levels of desion making, strategic, tactical and operational decisions. Van der Vorst et al (2007a) reported that the SCOR model directly addresses the needs of supply chain management at the operational level. The link between SCOR model processes and operational decision making are depicted in the model of Stewart (1995) which has been modified to show the link. This linkage can also be supported by Slats et al (1995) who stated that interactions between actors in a logistic chain is strongest at the operational level as compared to that at tactical and at strategic level (Figure 2).

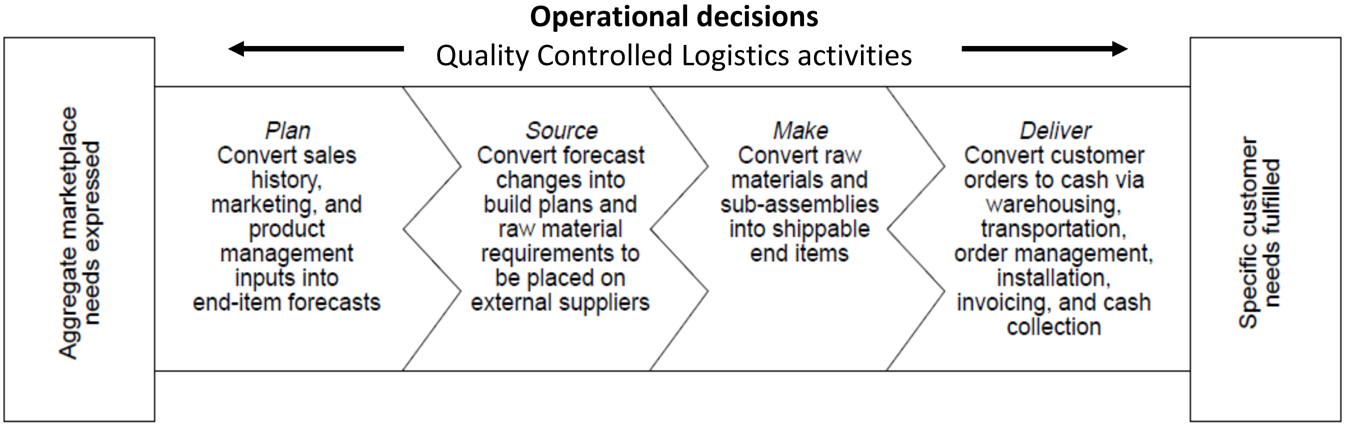


Figure 2: The integrated supply chain; modified from Stewart (1995) to include the element quality controlled logistics

One of the views of the SCOR model is that a supply chain must be measured and described in multiple dimensions. These dimensions include reliability, responsiveness, flexibility, cost, and efficiency of asset utilisation (Van der Vorst et al., 2007a). The advantages of the SCOR model are that it takes into account the performance of the overall supply chain, it proposes a balanced approach by describing performance of supply chain in multiple dimensions (Van der Vorst et al., 2007a). Van der Vorst et al (2007a) described the four key performance indicators within SCOR as; reliability measures (fill rate, perfect order fulfilment), cost measures (cost of goods sold), responsive measures (order fulfilment lead-time), and asset measures (inventories).

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

2.9 Quality Controlled Logistics

Quality Controlled Logistics (QCL) make use of variation in the product quality, developments in technology, heterogeneous needs of customers and the possibilities to manage product quality development in the distribution chain (Van der Vorst et al., 2007b). Quality distribution profiles are made by batching products of the same quality at the beginning of the supply chain and product differentiation is done by timely separation during harvesting and processing stages (Van der Vorst et al., 2007b). Van der Vorst et al (2007b) defined QCL as; *"that part of the supply chain process that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirement with respect to the availability of specific product qualities in time by using time-dependent product quality information in the decision process*."

Simply put, QLC involves use of time-dependent quality information of product properties to direct logistics activities in the chain. There is integration of time-dependent product quality information at all stages in the chain. Quality control and logistics control are integrated through the exchange of time-dependent information. Quality control involves measuring of product quality or process conditions, comparing to acceptable specifications or standards and taking correcting action if the measurements are out of the acceptable range. On the other hand, logistics control involves directing of products to the right place at the right time in the right quantity. To get a better understanding of quality controlled logistics, Table 9 adopted from Van der Vorst et al (2007b) shows the difference between decisions in a generic logistics food supply chain and those made in a supply chain that applies QCL. It can be seen that all logistics decisions made in a supply chain that applies QCL are based on time-dependent product quality information.

The presented literature is relevant to this study and is the basis of this study. The assumption of this study is that use of time-dependent quality information of product properties at identified critical control point will help to direct product such that product reach the customers before development of defect. Hence the literature is relevant and valid.

Table 9: Overview of specific QCL decisions

Generic logistics decisions	Specific QCL decisions
Determine customer serivce standards • Customer needs (quality, quality, e.t.c) • Customer service level • Dertermine requirements on supply of products in each stage of the chain	Determine customer requirements for specific market segments. Use product quality information to cluster harvested products into homogeneous batches and chose the best distribution channels
Determine facility network design • Number, location of stocking • Equipment selection • Capacity planning	Use product qiality information to determine required network design and equipment. Think about the use of RFID and GPS to capture the relevent infgormation
Determine inventroy management • Position Order Customer Decoupling points (CODP), push pull strageties • Warehousing policies	Use product quality information to determine position of CODP and specific environmental conditions in the complete supply chain needed to meet specific market segment requirements.
Determine information flows and order processing • Ordering rules • Order inventroy interface procedure • Order picking procedures	Use product quality information to apply First-Expired-First-Out (FEFO) policy. Focus on homogeneous product batches for specific market segments.
Determine transportation management • Mode selection • Vehicle scheduling • Freight consolidation	Use product quality information to determine transport mode and means (container, including environmental conditions) needed to meet customer requirements.

Figure 3 shows a comparison of a tradition supply chain where logistics activities are independent and a QCL chain where logistics activities and dependent on quality activities and time-dependent quality product information.

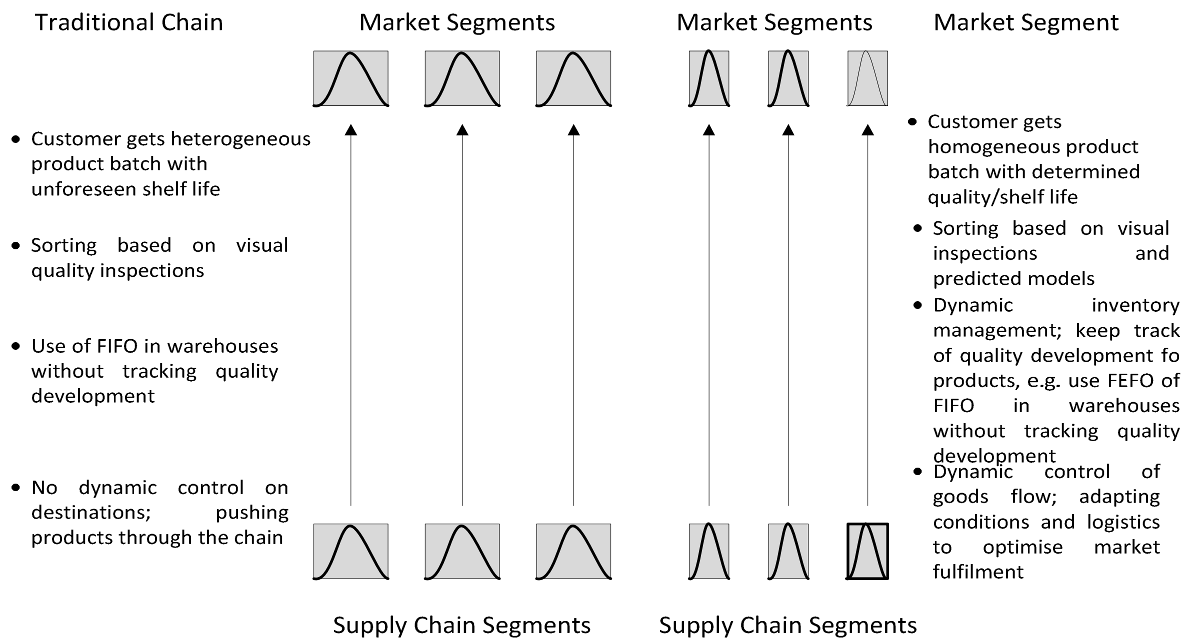


Figure 3: Comparison of tradition chain and QCL chain

2.10 Summary

In summary, major pre-harvest and postharvest defects of tropical fruit are mechanical defects and physiological defects. Dominant forms of mechanical defects are vibration injury, compression injury, abrasion injury and impact injury, and chilling injury, physiological pit and fruit softening are the dominant physiological defects. Major pre-harvest factors influencing incidence of defects are field temperature and nutritional imbalance. These factors influence incidence of chilling injury and/or freezing injury either due to high or low temperature during cultivation. Other defects are due to insect injury and invasion by pathogens.

Major postharvest factors influencing kiwifruit are defects temperature, relative humidity and fruit handling during at all stages in the chain. Vibration injury, abrasion injury, compression injury and impact injury are the major mechanical defects that occur during the postharvest stages and these mainly occur at harvesting and transportation stages. Handling of the kiwifruit during harvesting, sorting and transportation is the major cause of mechanical defects. Chilling injury, physiological pit and fruit softening are the dominant physiological defects during postharvest stage. These defects are time-temperature dependent and are dominant during storage and transportation stages.

There is a relationship between some pre-harvest factors and postharvest defects. Major pre-harvest factors influencing post-harvest defects are maturity of fruit at harvest, fruit composition (soluble sugars content and calcium concentration) and environmental conditions during harvesting. Postharvest physiological defects that include chilling injury, fruit softening and physiological pit are influenced by these pre-harvest factors.

Logistical factors such as inventory issuing system, warehouse management and level of information system being practiced have an influence of losses or wastage due to development of defects in agri-food supply chains were also presented in this chapter. In order to prevent or minimise influence of the above discussed factors on development of defects and resultant losses or wastage, control measures need to be applied at identified critical control points in the chain.

CHAPTER 3 CONCEPTUAL FRAMEWORK & RESEARCH MODEL

In this chapter, a conceptual framework is presented and the framework gives an overview pre-harvest and postharvest factors that influence the incidence of kiwifruit defects. Pre-harvest factors that influence formation of defects and the critical points at which formation of the defects can be prevented are also mentioned, Figure 5 and 6 respectively. Logistics factors that can influence incidence of defects are also presented in this chapter (Figure 7). Lastly, a research model developed on the basis of the extensive literature analysis and the conceptual models is presented (Figure 8).

3. 1 Conceptual framework

A translation of operational decisions of the four processes in the SCOR model (Plan, Source, Make and Deliver) into quality controlled logistics decisions that can be made to reduce fruit losses is made in Table 10. The QCL decisions presented in Table 10 are derived from literature analysis in section 2.8

Table 10: Decisions within Quality Controlled Logistics (own illustration)

SCOR Processes	Decisions within Quality Controlled Logistics
Plan	• Decide on number of actors to collaborate with to be able to meet customer demands • Decide of varieties to plan • Decide on sourcing areas • Decide on the market segments to target • Decide on type and level of integration and coordination in the chain • Decide on type of information system and whether to centralize the information system • Predict the likelihood of mechanical and physiological defects occurring • Identify critical points where both logistics and quality control activities should be implemented in the chain • Decide on Customer order decoupling points (CODP) e.g. make-to-order or make-to-stock
Source	• Establish acceptance quality standards • Decide on maturity stage to harvest the fruits • Decide on harvesting frequency and environmental conditions under which to harvest fruits • Decide on method of harvesting that do not cause fruit injury • Decide on the frequency of quality inspections and measurements to be carried out
Make	• Decide on type of packaging material, cushioning material, crate size and batch size to use. Pack the right amount of fruits to avoid impact and compression damage. • Determine time-temperature conditions to store the fruits and logistics and quality control activities required to maintain fruit quality
Deliver	• Decide of mode of transportation to use considering acceptance period of the fruit, fruit quality, quality decay models and also distance • Decide of time-temperature conditions to transport the fruits • Decide on the inventory issuing policy to use taking into account fruit quality, predictions on incidence of fruit defects and also quality decay models

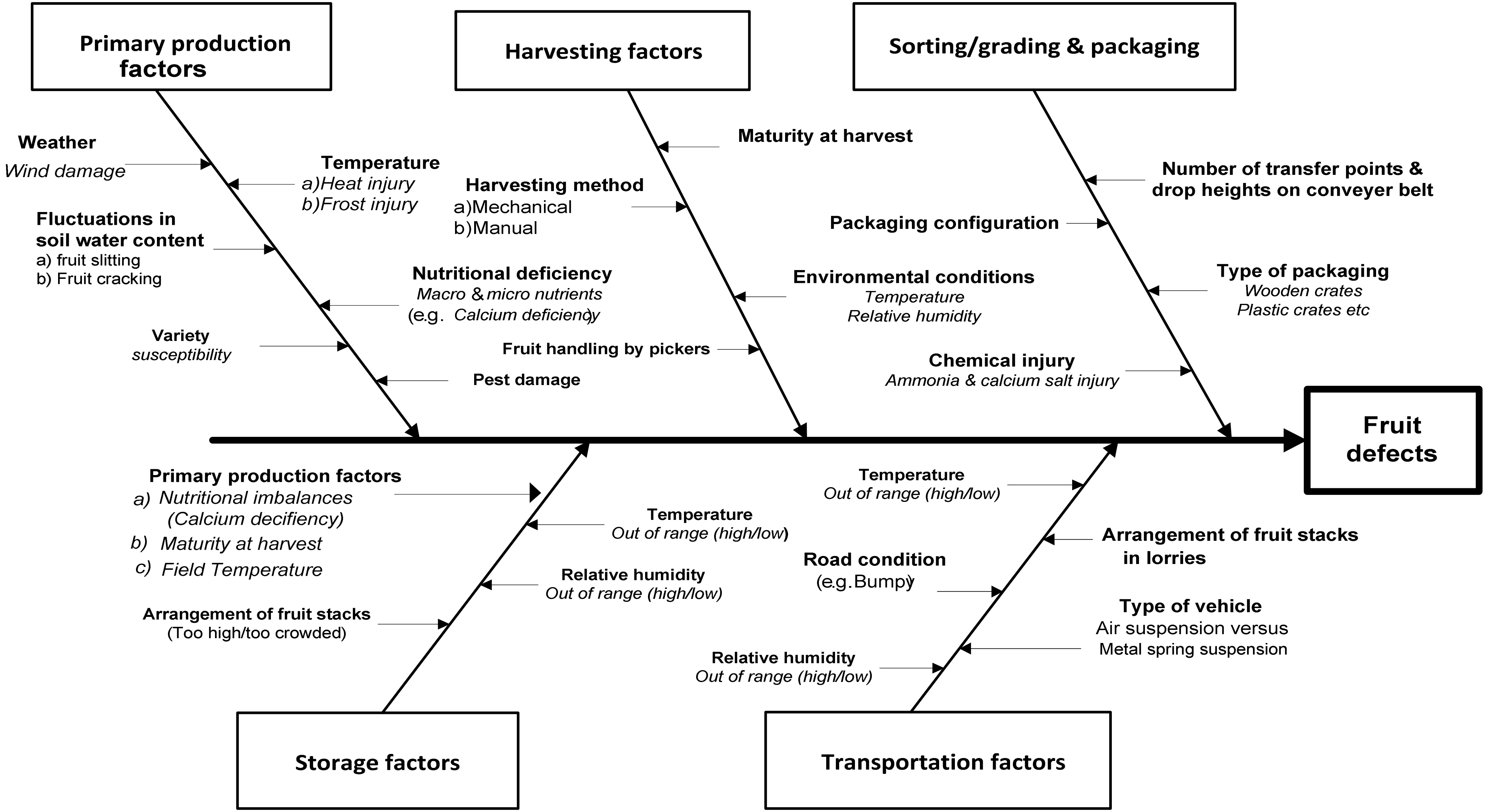


Figure 5: Cause-and-Effect diagram of factors influencing pre-harvest and postharvest fruit defects

Kirkby, et al (2004), Ladaniya (2008), Timm, et al (1996), Lallu, et al (1999), Martinez-Romero, et al (2004) Lurie and Crisosto (2005), Maguire et al (2004) and Sfakiotakis, et al (2005), Burdon, et al (2007), Ferguson, et al (1999), and Kader and Rolle (2004)

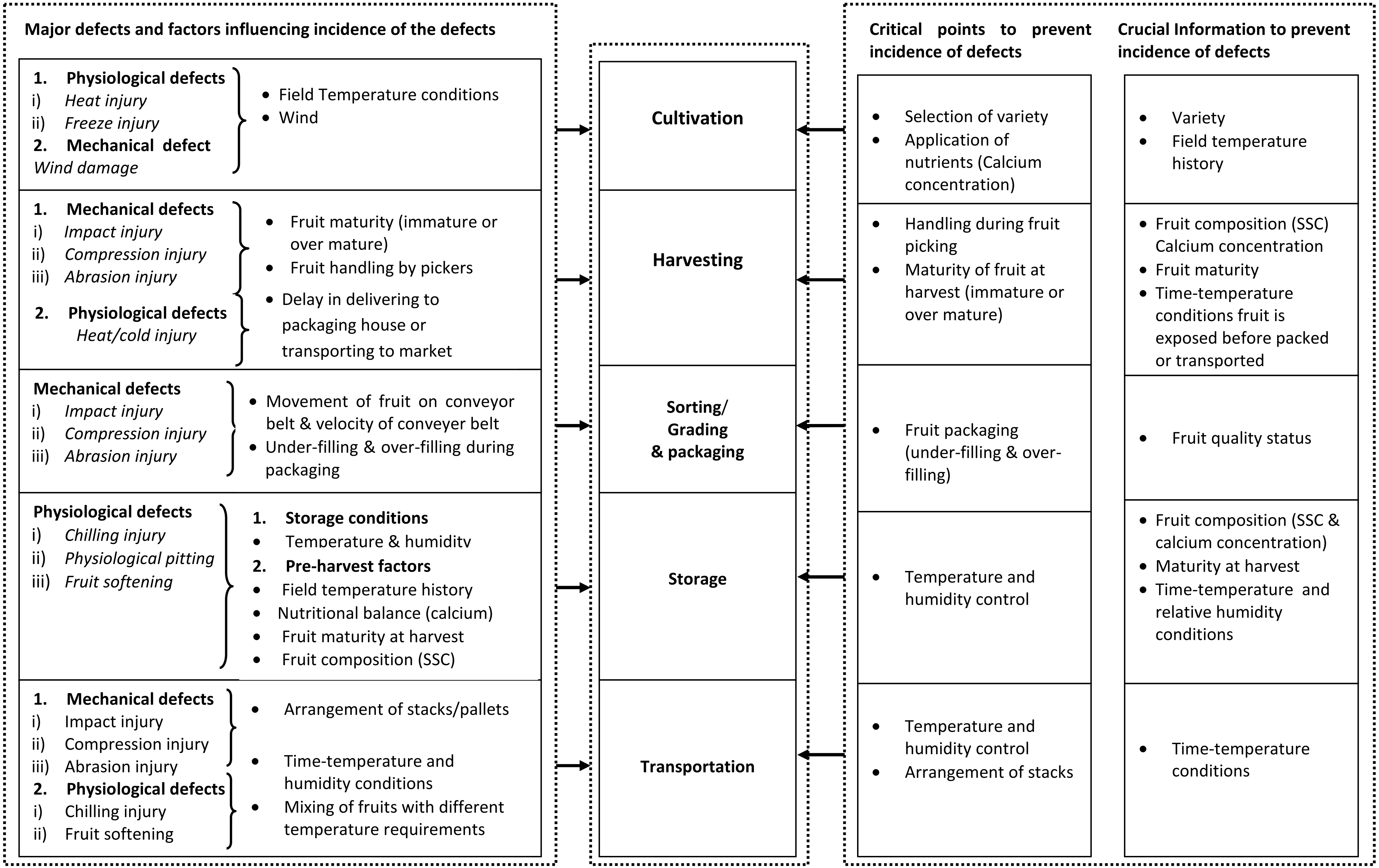


Figure 6: Critical Control Points at which defects can be prevented or minimised (own illustration)

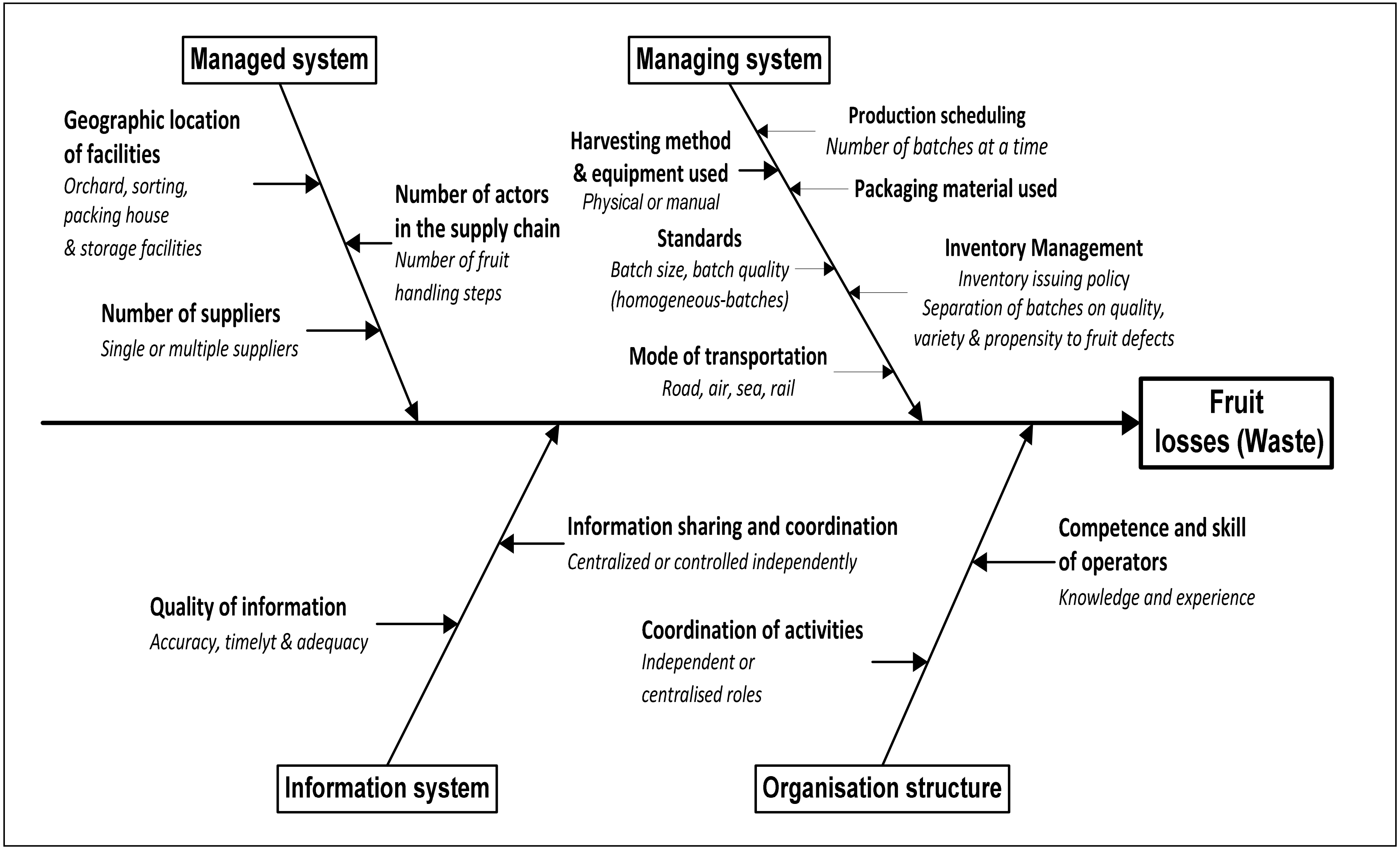


Figure 7: Cause-and-effect diagram of logistical factors influencing fruit losses due to incidence of fruit defects in the supply chain

Monczka et al. (1998), Alvarez (1994), Vorst Van der (2000), Van der Vorst et al. (2005), (Vorst van der, et al., 2007, Ferguson and Ketzenberg (2006), Zhang and Wilhelm, (2009), Ferguson, et al (1999), and Kader and Rolle (2004 and Semini, et al., 2008

3.2 Research Model

The research model (Figure 9) is developed from the comprehensive literature analysis done in Chapter 2 and the theoretical framework developed in section 3.1. The research model consists of four major elements (Figure 9); (i) quality controlled logistics (ii), physical process and critical control points (iii) contextual factors and, (iv) outcome factors. Arrows reflect the relationship between these elements. Using information in the conceptual model, the assumption is that incidence of fruit defects at identified critical control points within the physical process is influenced by the level of quality controlled logistics. The level of quality controlled logistics is also assumed to be influenced by the complexity of contextual factors of a given supply chain. The outcome factor is percentage produce loss in the chain. Each element of the research model is discussed below;

A. Contextual factors

Contextual characteristics are inputs of the research model and they put requirements on the system and have influence on the performance of the system (Van der Spiegel et al., 2003). Van der Spiegel et al (2003) further stated that contextual factors are part of the environment in which a company operates that affect the production quality. A context factor can also be defined as a structural element of the situation that can affect activities in a system and its performance (Luning et al.) Four contextual factors; product characteristics, process characteristics, chain characteristics and market characteristics, adopted from the MSc Thesis of Deelen (2009) are considered in this model. The context of agri-produce supply chains can differs in aspects such as stability of quality attributes, for example, product such as cut flowers are very susceptible to moisture loss and their shelf life is reduced if exposed to temperatures, above 8 ^{0}C for a longer duration (Reid, 2000a), whereas fruits such as bananas have a wide optimum temperature range of 13 ^{0}C to 25 ^{o}C (Jiang et al., 2002). Also strictness of customer requirements varies with supply chains. Different chains might require different levels of quality controlled logistics control to achieve the same percentage of losses depending on the complexity each chain.

It is assumed that the level of quality controlled logistics required to prevent or reduce level of losses in fresh agri-produce supply chain is influenced by the contextual factors within a given chain. A higher complexity of contextual factors is expected to relate with a higher level of control to prevent or minimise loses that are due to defects. Studies of Van der Spiegel et al (2003) on the influence of contextual factors on the level of food quality management in the bakery sector revealed that larger complexity of contextual factors was related to a lower production quality, but quality increased when the level of quality management improved.

B. Quality Controlled logistics

In the research model (Figure 9) quality controlled logistics is sub-divided into three sub-elements namely quality control, logistics control and the third sub-element is an integration of quality control and logistics control by use of time-dependent product quality information. Each such-element if described below;

Quality control

In fresh agri-produce supply chain different quality attributes and different parameters have to be controlled in order to maintain the quality of the product until it reaches the final consumer. Luning et al (2007) defined quality control as a basic activity of food quality management with the objective to keep product properties, production processes, and human processes between certain acceptable tolerances. Evans and Lindsay defined (2004) defined quality control as an on-going process of evaluating performance of both technological and human processes and taking corrective actions when necessary. In this model, the objective of quality control is to prevent or reduce development of fruit defects at all identified critical control points supply chain through quality inspections, monitoring chain conditions and taking corrective action whenever chain conditions are not within acceptable optimum range. Luning et al (2008) suggested that technological activities that are based on the use of more scientific-based knowledge, critical analysis, use of specific information, more procedural methods and more systematic activities can result in higher levels of quality control.

Quality control can be best explained using quality control circles. According to Luning and Marcelis (2009), quality control circle in food production and processing can be described in four activities namely; measuring product parameters, testing and comparing against standard, regulating to determine the direction the product or process must be corrected, and lastly, taking corrective action when measurements taken are out of range. In this model, the feed-forward control circle (Figure 8) best depicts the control mechanism that is applied.

According to Opara and Mazaud (2001), in order to control quality, one must be able to measure quality-related attributes so that comparison can then be made to set standards. Kader (1999) also reported that measuring quality attributes of produce is important in quality management during produce handling. Effective quality control practices prevent substandard actions in the chain, from production to packing and delivery of produce (Opara and Mazaud, 2001). Lidror and Prussia (1993) suggested that to achieve quality of conformance, a systematic approach should be followed to control the main handling stages.

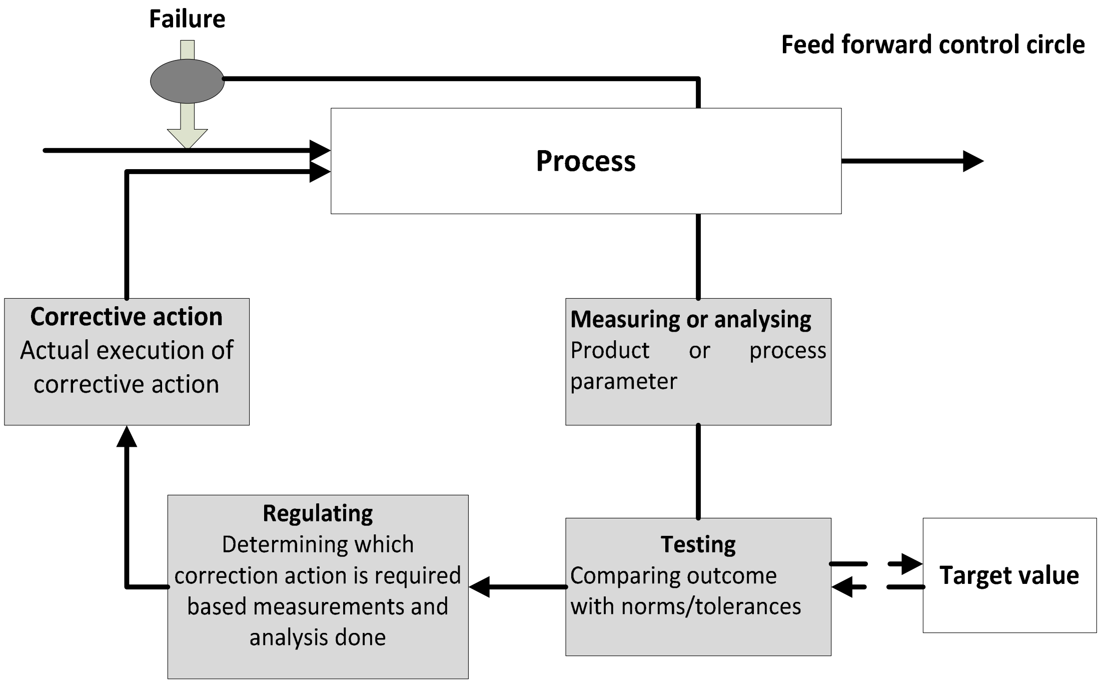


Figure 8: Quality Control Circle (adapted from Luning and Marcelis 2009)

Quality inspections are important to monitor and evaluate product quality. Quality inspections can be done either on a continuous basis where frequent quality checks are done along the packing lines, or on a sample basis where representative samples are randomly selected and inspected to determine whether the product meets the grade specification for which it is packed (Kader, 2001b). Data from the inspections and measurements can be used for corrective actions and as a guide on how to manage subsequent operations efficiently Abbott (1999). Statistically valid sampling at every critical point to determine if processes are under control and to identify corrective actions is the main means of controlling the quality of agricultural products as they flow in the supply chain (Opara and Mazaud, 2001). Fours indicators derived from literature analysis are used to assess level of quality control and these indicators presented in the later sections.

Logistics control

This sub-element of quality controlled logistics involves directing of products to the right place at the right time in the right quantity and at a reasonable cost. This puts challenging requirements on the agri-food chain and there is a need to make the right logistics decisions so as to meet customer expectations (Van der Vorst et al., 2005). Most of the literature on logistics control has already been presented in section 2.8. Three indicators derived from literature analysis are used to assess level of logistics control and these indicators presented in the later sections.

Integration of quality control and logistcis control

The third sub-element involves integration of logistics control and quality control through use of time-dependent product quality information. All logistics activities are dependent on time-dependent product quality information obtained through quality control activities. The assumption is that use of time-dependent quality information of product properties will help to direct products such that the products reach the intended customers before development of defects. A higher level of integration of quality control and logistics control activities is reflected by a use sophisticated methods to predict incidence of fruit defects, exchange of quality information in the chain and flexibility of the delivery systems to match specific consumer requirements. Most of the literature on logistics control has already been presented in section 2.8. Three indicators derived from literature analysis are used to assess level of logistics control and these indicators presented in the later sections.

C. Physical Process and Critical Control Points

The third element of the research model shows the most common physical process in most tropical fruit and fresh agri-produce supply chains. Critical control points in the chain are also indicated in this physical process. It is assumed that control activities at these critical control points can help to prevent or reduce development of the defects at that particular point and/or at subsequent stages in the chain.

Physical process

Cultivation, harvesting, sorting and packing, storage and transportation are the stages in the fresh agri-produce supply chain that are considered in the model.

i. Cultivation

Cultivation is an important stage in fresh agri-produce supply chain and has an influence on incidence of both pre-harvest and postharvest defects. Benitez et al (2004) reported that the cultivar is the first and main factor influencing development of physiological disorders in tropical fruits. For example, in kiwifruit, Gold kiwifruit (Hort16A) is softer than Hayward at commercial maturity (Kirkby et al., 2004) and more vulnerable to mechanical damage during harvesting and physiological disorders during storage (Burdon et al., 2007). Environmental conditions and nutritional factors during cultivation are also important factors as they have an influence on incidence both pre-harvest and post-harvest defects. For example, field temperature conditions can influence incidence of fruit defects such as heat injury or freezing injury (Martinez-Romero et al., 2004) and nutritional factors have an influence on the development of postharvest physiological defects during storage such as physiological pit, chilling injury or fruit softening (Burdon et al., 2007).

ii. Harvesting

Harvesting is an important stage in tropical fruit supply chain as improper harvesting and handling can cause extensive fruit injuries resulting in immediate decreases in percentages of fresh fruit available for marketing and increase in decay during storage or transit (Ladaniya, 2008). Bruising, stem-end tears, scratching, and pitting of fruit are common injuries as a result of poor human handling during harvesting (Ladaniya, 2008). The main factor affecting the sensitivity of fruits to mechanical damage is the harvesting system. For example, the impact of mechanical damage is different depending on whether picking is done manually or mechanically (Martinez-Romero et al., 2004).

iii. Sorting and packing

The first set of post-harvest operations along the tropical fruit supply chain includes grading or sorting and packing stages. Sorting and packaging processes are an essential part of the kiwifruit distribution system (Kilgour et al., 2008). Common fruit defects during sorting and packing are abrasion, impact damage and compression damage. Inappropriate packaging such as overfilling or under filling can result in physical damage of produce due to compression or abrasion respectively. Therefore, it is important to look at the sorting and packing stages in this study.

iv. Storage

Most tropical fruits such as Kiwifruit should be stored as near to $0^{o}C$ as possible and under 90 - 95 % relative humidity (Crisosto and Kader, 1999). According to Rirenour et al (1999), kiwifruit can be successfully stored at 0°C for 4 to 6 months but softens markedly when exposed to even minute concentrations of ethylene. Care should be taken to assure than the storage temperature is not lower than $0^{o}C$ to avoid freezing damage. For long-term storage, use of controlled atmospheres has been shown to be effective provided that both $0^{o}C$ and ethylene less than 50 ppb are maintained (Crisosto and Kader, 1999).

v. Transportation/distribution

Many of the losses that occur during transportation are due to inappropriate packaging and box arrangement inside the lorries (Beattie and Wade, 1998). Common types of mechanical damage during transportation or distribution are impact damage through dropping, compression damage due to high stacking, and vibration damage (Kitinoja and Kader, 2002). Although packaging is supposed to protect fruits from physical damage during transportation and handling, the degree to which vibration will influence fruit quality is dependent on the type of packaging (Lallu et al., 1999). Vibration injury is common during transport resulting in abrasion marks and cuts ranging from light rubbing to removal of the skin and possibly some of the flesh (Wills et al., 1998). Compression injury is also a common fruit defect induced during transportation. Symptoms of compression injury include bruises, cracks, splits, and deformation (Martinez-Romero et al., 2004).

Critical Control points

Based on literature review and the conceptual model developed in earlier sections, five critical points have been identified; (i) maturity stage at harvesting, (ii) handling during kiwifruit picking, (iii) fruit packing (under-filling & over-filling), (iv) stacking of fruit batches during storage & transportation, and (v) monitoring and control of temperature and relative humidity. It is important to identify critical points at which incidence of fruit defects is induced along the entire kiwifruit pre-harvest and postharvest chain.

(i) *Maturity stage at harvesting*

Maturity of kiwifruit at harvest strongly influences susceptibility to postharvest disorders such as fruit softening, chilling injury and physiological pit (Clark et al., 2004). This is supported by Maguire et al (2004) who stated that maturity of kiwifruit at harvest is a key indicator of the development of postharvest disorders as there is higher risk of physiological pit disorder in more mature kiwifruit and chilling injury in less mature kiwifruit. In studies conducted by Sfakiotakis et al (2005), late harvested kiwifruit were found to be less susceptible to chilling injury than early harvested fruit.

Burdon et al (2007) stated that more mature kiwifruit has a higher content of soluble solids concentration more firm and are less susceptible to chilling injury. This is consistent with earlier reports by Mitchell and Kader (1998) who stated that chilling injury pattern normally relate to the pattern of soluble solids content of the fruit. A higher incidence of physiological pit during long storage duration of more mature kiwifruit compared to low incidence in fruit harvested at early maturity was reported in studies done by Sfakiotakis et al (2005). Cooper et al (2007) reported that kiwifruit harvested more mature with more than 9% soluble sugar content soften most quickly and early harvested kiwifruit with or below 5.5% soluble sugar content are less susceptible to softening.

Effectively managing harvest maturity is essential to obtaining optimum storage potential and to reduce kiwifruit loss during storage (Sfakiotakis et al., 2005). This makes maturity stage at which kiwifruit is harvested a critical point where physiological defects such as chilling injury and physiological pit can be prevented or reduced by harvesting the fruit at the most appropriate maturity stage. Prevention or reduction of physiological disorders is not evident during the harvesting period but is during subsequent stages in the chain, especially during storage and transportation stages when other chain conditions that include relative humidity and temperature are adjusted accordingly.

(ii) *Fruit handling during harvesting*

Improper harvesting and handling cause extensive fruit injuries resulting in immediate increase in fruit decay during storage or transportation (Ladaniya, 2008). Compression and impact forces on fresh fruit associated with manual harvesting and handling have been found to have significant negative effects on their quality during storage (Martinez-Romero et al., 2004). Stem-end tears, scratching, deformation of fruit due to compression, and abrasion of fruit are common injuries as a result of poor human handling during harvesting (Ladaniya, 2008). The picker is normally the greatest potential cause of bruise damage due to amount of pressure applied (Martinez-Romero et al., 2004), especially when two or three fingertips are used to pull the fruits (Beattie and Wade, 1998). Also, if kiwifruit does not detach easily from the plant it can be injured by the force of the hand (Beattie and Wade, 1998).

Fruit handling during picking of fruits is therefore a critical point for the prevention of mechanical defects such as compression injury, impact injury and abrasion injury. Martinez-Romero et al (2004) reported that daily quality inspections of harvested fruits are key factors for minimising fruit damage in orchard because if damage is detected during the harvest, the human and mechanical failures can be reduced. Kader and Rolle (2004) reported that motivated employees who are careful and diligent in their handling of produce can help to minimize losses due to mechanical injury as a result of human handling at harvesting stage. Training and supervision of workers is important (Kader and Rolle, 2004) and there is also need for adequate instruction on proper fruit handling techniques and supervision of personnel (Martinez-Romero et al., 2004).

(iii) *Fruit packing*

Fruit packaging is a critical point at which incidence of mechanical defects can be reduced or prevented. Common fruit defects during sorting and packing are abrasion, impact damage and compression damage. Compression and abrasion injuries are dominant at this stage are due to inappropriate packaging such as overfilling or under filling. Compression bruising can also occur during packaging due to pressure of overlying fruit in a stack (Beattie and Wade, 1998). Chonhenchob and Singh (2003) stated that the packing configuration can greatly affect the bruising of fruit. Containers should not be filled either too loosely or too tightly as loose products may vibrate against others and cause bruising, while over-packing results in compression bruising (Kitinoja and Kader, 2002).

(iv) *Control of temperature and humidity in the chain*

Temperature during storage and transportation of kiwifruit this is a control point for development of physiological disorders such as chilling injury, fruit softening and physiological pit. Kiwifruit is susceptible to the development of physiological storage disorders such as softening, chilling injury and physiological pit during prolonged low temperature storage (Lallu, 1997). If temperatures drop below the optimum range for a, freezing injury may result while elevated temperatures will result in physiological pit. Maguire et al (2004) reported that incidence of physiological pit is 30 times more likely to occur during storage at 1.5 ^{0}C than during storage at 3 ^{0}C. On the other hand, incidence of chilling injury in kiwifruit is greater during longer storage duration for fruit harvested when less mature and stored at 1.5 ^{0}C. The softening process in kiwifruit is temperature dependent (Arpaia et al., 1994) Fruit held at 2.5^{0}C softens substantially faster than fruit stored at 0^{0}C (Arpaia et al., 1994). Also, time-temperature has a large impact on the ethylene production and ethylene stimulates fruit ripening resulting in fruit softening (Korsten, 2006).

As such, temperature condition during storage and transportation is a critical point at which proper time-temperature regulation can help prevent or reduce incidence of fruit defects during storage and transportation of kiwifruit. Inappropriate temperature conditions could exacerbate the incidence of physiological defects. Consequently, it is important to control the time-temperature during storage and transportation so that development of defects can be suppressed.

(v) *Arrangement of fruit stacks or batches*

Compression damage due to high stacking and overfilling of packs (Kitinoja and Kader, 2002) and vibration damage due to poor stacking methods are common during transportation of fruits (Beattie and Wade, 1998). Many of the losses that occur during transportation are due to inappropriate packaging and batch arrangement inside the lorries (Beattie and Wade, 1998). During transportation, vibration injury can be induced by vibrations resulting from inappropriate arrangement of stacks (Wills et al., 1998).

Inappropriate arrangement of stacks can also result in high temperature injuries. Tanner and Amos (2003) reported that batches must be stacked in a way that enable proper air circulation in order to facilitate removal of heat from the produce as well as to remove incoming heat from the atmosphere. Produce should not be densely stacked so that cold air circulation is blocked or so high that it is out of the refrigerated zone and becomes exposed to ambient air temperatures (Tanner and Amos, 2003). Therefore, stack arrangement during storage and/or transportation is a critical point at which proper arrangement of fruit batches can help prevent or reduce incidence of fruit defects such as compression injury and fruit softening.

D. Performance indicators/Outcome factors

Van der Vorst et al (2000) defined performance indicators are operationalised process characteristics which compare the performance of a system with a norm or target value. Performance indicators help to quantifying the efficiency and effectiveness of an action (Gunasekaran and Bulent, 2007). The purpose of measuring performance is to (a) identify success, (b) identify whether customer needs are met; (c) help the organisation to understand its processes and to confirm what they know or reveal what they do not know, (d) identify where problems, bottlenecks or waste exist and where improvements are necessary, (e) ensure decisions are based on facts, not on supposition, emotion, faith or intuition, and (f) show if improvements planned actually happened (Gunasekaran and Bulent, 2007).

Two performance indicators or outcome factors are used in this model; (i) percentage incidence of defects in the chain and, (ii) percentage of produce thrown away as waste due defects. These outcome factors help to assess the influence of level of quality controlled logistics on incidence of defects and percentage loss of due to these defects in respect to contextual factors in a given fresh agri-produce supply chain.

The hypothesis specific hypothesis is that;

Level of quality controlled logistics required to prevent or reduce incidence of defects at identified critical control points is dependent on the complexity of the contextual factors in a given fresh agri-produce supply chain. The more complex the contextual factors the higher the level of quality controlled logistics required to minimise food losses to an acceptable level in the fresh agri-food supply chain.

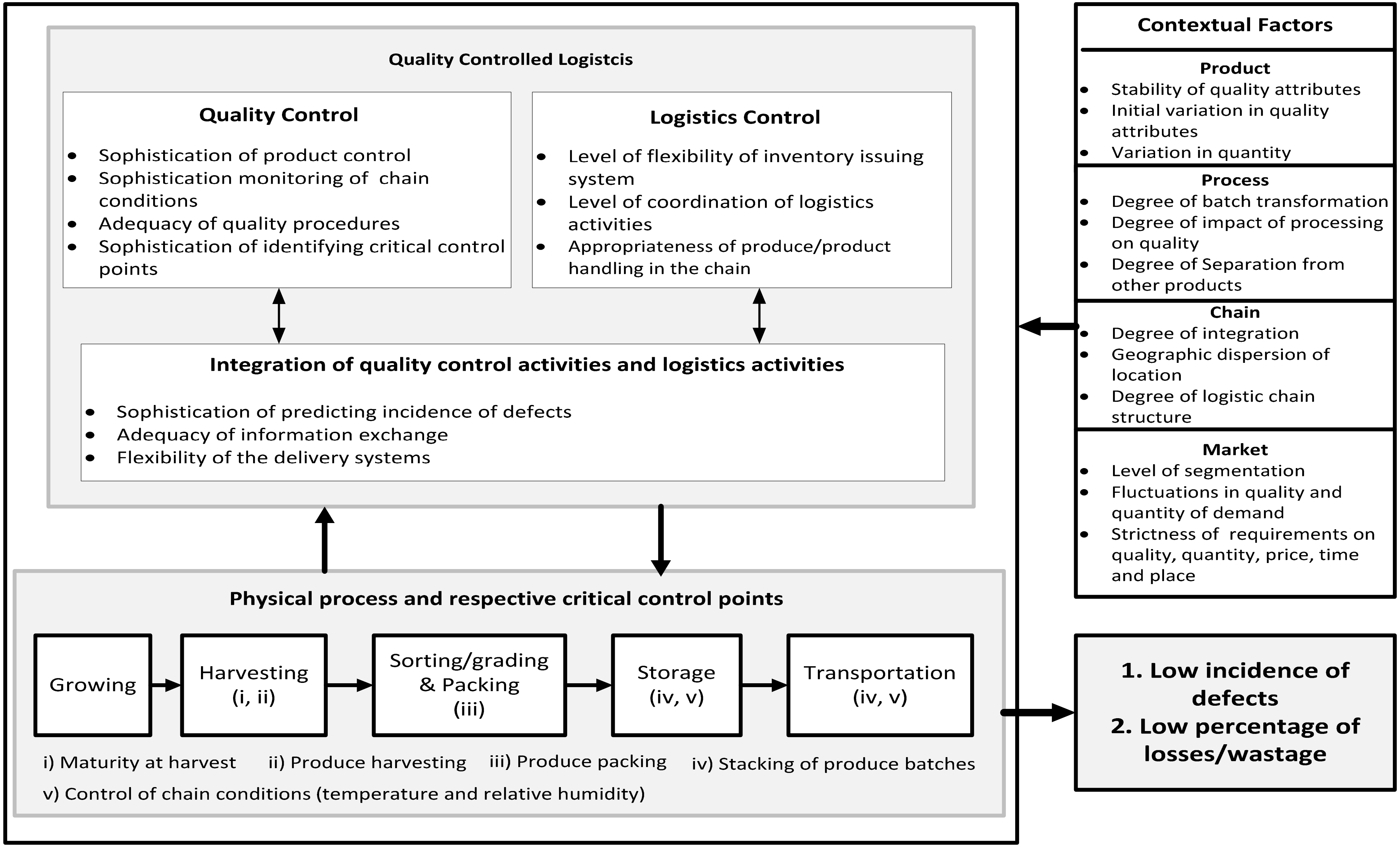


Figure 9: Research Model

3.3 Indicators for the respective elements of Quality Controlled Logistics

Indicators to assess the level of quality controlled logistics in the agri-produce supply chain are discussed in this sections. These indicators are derived from literature analysis and the indicators are discussed for each of the three sub-elements of quality controlled logistics control system described in the model.

Indicators for Quality Control

It is assumed that a high level of quality control will result in reduced incidence of fruit defects and subsequently reduced food losses. In this study, a higher level of quality control is reflected by a use of sophisticated methods for product control, use of sophisticated methods to monitor technological conditions and use of appropriate fruit handling procedures.

i. Sophistication in product control

This indicator measures the degree of sophistication in quality control activities in the chain. Sophistication in measuring, testing, regulating and corrective action activities is considered. The assumption is that use of statistically valid sampling methods, use of accurate and responsive equipment to measure, test or regulate critical processes or product parameters will result in better detection of defective fruits, detection of fruit's potential to develop defects and also provides objective information that can be used to predict incidence of fruit defects in the chain.

According to Tijskens et al (2003) adequate and sensitive techniques for measuring quality related properties provides the necessary means to detect and evaluate the skewness of quality distribution in product batches. Opara and Mazaud (2001) stated that statistically valid sampling at every critical point to determine if processes are under control and to identify corrective actions is the main means of controlling the quality of agricultural products as they flow in the supply chain. Kader (2001a) reported that achieving and maintaining uniformity of inspection is important to ensure equity and harmony and there is need to train inspectors to apply the standards, use visual aids such as colour charts, models, diagrams and photographs and also to use objective methods for determining quality and maturity whenever feasible and practical.

Advanced objective methods such as use of computer vision are reported to be helpful during quality inspections and also provide objective assessment of fruit quality (Ladaniya, 2008). Brosnan and Sun (2002a) reported that computer vision systems can be used for inspection and evaluation purposes as they provide consistent and objective assessment. Using machine vision helps to automate manual grading practices, standardise techniques and eliminate tedious inspection tasks (Abbott, 1999). Timmermans (1998) stated that the human eye is very good in recognising different patterns but has limited capabilities to perform objective estimates of size and shape.

A high level of sophistication in product control is characterised by use of objective, automated, highly sensitive, and precise equipment such as automated inspection systems and computer vision systems to measure, test, and regulate product parameters at every identified critical control point in the chain. Statistically underpinned and tailored sampling is used at every critical point to draw samples to measure and test product parameters. Corrective action is promptly taken whenever fruit's propensity to develop defects is detected defective fruit is detected.

ii. Sophistication in monitoring of chain conditions

This indicator assesses sophistication in monitoring of technological conditions, mainly temperature and relative humidity in the chain. The assumption is that use of advanced and highly sensitive sensors and recorders that are regularly maintained will result in better monitoring of temperature and relative humidity conditions. Dome´nech et al (2008) defined monitoring as the scheduled measurement or observation of a given operational parameter at a critical point relative to its critical limit. Monitoring is responsible for assuring that the process is under control at any given moment (Dome´nech et al., 2008).

Dome´nech et al (2008) reported that there is a need to have a monitoring system that is accurate and reliable for ensuring the detection and warning of any deviations. High precision in monitoring equipment is also very important. Ladaniya (2008) stated that for a high degree of accuracy and/or sensitivity, sensors with platinum resistance elements should be used. According to Dome´nech et al (2008) a typical temperature detector of good quality should have a tolerance of 0.5 ^{0}C. Besides precision of monitoring equipment, routine maintenance and calibration schedules should be implemented to ensure reliable operation of the monitors (Kader and Rolle, 2004). Also, when monitoring temperature during storage or transportation, Kader and Rolle (2004) mentioned that fruit temperature rather than atmospheric temperature should be measured as it gives the actual temperature of the fruit compared to measuring atmospheric temperature which just give an indication of the condition of the fruit's surrounding environment.

A high level of sophistication in monitoring is taken to be characterised by systematic monitoring using advanced modern technology that is precise, accurate and reliable. Advanced monitoring equipment is reflected by use of time-temperature indicators. Time-temperature indicators have the advantage of indicating the cumulative time–temperature history of the products (Hoogerwerf et al., 1994). Time-temperature indicators measure both time and temperature and integrate them into a single visible result (Hoogerwerf et al., 1994). Giannakourou and Taoukis (2003) indicated that the amount of rejected products in the distribution system can be minimised using a TTI-based monitoring system as it enables the classification of products according to keeping quality/shelf life remaining. Venugopal (2006) stated that time-temperature Indicators (TTI) are have a great potential satisfy the thermal monitoring requirements.

iii. Adequacy of quality procedures

This indicator measures the availability of fruit handling procedures in the chain. The assumption is that having handling procedures that are readily available to all employees, simple, precise, easy to understand and practicable, will reduce damage inflicted by human handling in the chain. A high level of availability of fruit handling procedures is characterised by having handling procedures that are accessible to every employee, written in a language understandable to all employees, simple, precise and whose content is continuously revised to match any changes in control system. Visual aids such as charts, diagrams or photographs are used to make the procedures more understandable.

Brown et al (1993), reported that besides supervision and daily quality inspections, adequate instructions on proper fruit handling techniques is a key factor to minimising fruit damage. Further, Brown et al (1993) noted that provision of instructions that are easily understandable by the pickers is essential to ensure that fruit damage during fruit handling is minimised. According to Opara (2009) handling and quality procedures must be understood easily, simple, precise. This is supported by Martinez-Romero et al (2004) who also argued that there is a need for provisions of simple and precise instructions on proper fruit handling techniques to employees in order to reduce fruit damage during fruit handling operations in the chain.

iv. Sophistication of identifying critical control points

This indicator is used to assess the criteria upon which critical control points are established in the chain. The assumption is that a higher level of scientific evidence and use of a systematic way to establish critical control points will result in more reliable and accurate control points which will reduce incidence of fruit defects. According to Luning et al (2008) establishment of a more appropriate critical control point will result in more reliable and accurate control points. Luning et al., (2009) mentioned that control processes should be focused on critical points as they provide a high level of prediction.

A high level criterion is characterised by having a systematic way that uses scientific knowledge to identify the critical control points in the chain. Scientific expertise and scientific evidence on factors influencing incidence of defects and on the relationship between pre-harvest and post-harvest factors is used to establish the critical points. Dome´nech et al (2008) stated that a complete and accurate determination of critical control points is fundamental to controlling quality deterioration. Dome´nech et al (2008) further suggested that there is need for an intimate understanding of the interaction between process and product in establishment of the critical control points.

Indicators for Logistics Control

Logistics control is primarily based on the time a certain product needs to be at a certain place with the right quality and at a given time. To ensure that the request by consumer for fresh products with elevated quality standard is fulfilled, there is need for tight and careful stock management at each stage along the chain (Dada and Thiesse, 2008). In this study, a higher level of logistics control is reflected by a use of highly flexible inventory issuing system, coordination of logistics activities and/or processes in the chain and appropriate handling of fruit in the chain. These three indicators are discussed in detail below;

i. *Level of flexibility in inventory issuing system*

This indicator assesses the ability of the inventory issuing system to respond to changes in fruit quality and environmental conditions. Bowman et al (2009) reported that in any produce batch each individual product can has a different deterioration history and thus a different remaining shelf life, hence there is a need for an inventory issuing system that takes into account the remaining shelf life of a product. The assumption is that an inventory issuing policy that is based on time-dependent quality information, quality decay models, prediction of incidence of fruit defects and chain conditions is most likely to pick fruit batches that are at risk for distribution first before development of the fruit defects. This will reduce incidence of fruit defects in the chain and subsequently, fruit loses in the chain.

A high level ability of the inventory issuing system to respond to changes in fruit quality and environmental conditions is characterised by an inventory issuing system that is based on time-dependent quality information, quality decay models, predictions on product incidence of fruit defects and chain conditions. Such an inventory system is not standard and rigid but depends on the quality of a given fruit batch at a given time.

In their studies, Bowman et al (2009) reported that for fresh and frozen goods, the shortest-remaining-shelf-life (SRSL) policy outperformed LIFO and FIFO policies. Giannakourou and Taoukis (2003) reported that the amount of rejected fresh food products can be minimized using quality and time-temperature based inventory management system such as FEFO, LQFO or HQFO. This is supported by Dada and Thiesse (2008) who mentioned that when the primary objective is to avoid spoilage and to sell items with qualities that vary as little as possible, LQFO is the best issue policy. Van der Vorst et al (2007b) suggested that new stock rotation systems can be implemented which are not based on fruit age, FIFO or LIFO, but also based on fruit quality, such as on First-Expired-First-Out (FEFO), Highest-Quality-First – Out (HQFO) or Lowest-Quality-First-Out (LQFO) issuing policy. Dada and Thiesse (2008) that when the primary objective is to avoid spoilage and to sell items with qualities that vary as little as possible, LQFO is the best issue policy.

ii. *Level of coordination of logistics activities*

Logistics coordination refers to specific logistics operational activities that coordinate the flow of materials from suppliers to customers throughout the supply chain (Stock et al., 2000). This indicator is reflected by the extent to which logistics activities and/or processes are coordinated and standardised throughout the chain. The assumption is that coordination and standardising transportation, handling equipment, packaging, pallets or crates will reduce handling of fruits and number of fruit handling stages in the supply chain and this effectively reduces losses that are due to mechanical fruit damage that normally occurs during fruit handling (loading and uploading, changing of crates or packaging).

Lockamy and McCormack (2004) identified collaboration as the most important indicator of a supply chain in the plan, source, make and deliver areas, processes of the SCOR model. Dekker and Van Goor (2000) highlighted that physical integration of logistics processes improves the efficiency of the physical flow of products between actors in the chain. This is also supported by Brecht (2003) who noted that use of standard container sizes that fit interchangeably on the size of the pallet helps to promote efficiency in the distribution system. According to Dekker and Van Goor (2000) adjustment and/or standardisation of transportation and material handling equipment, such as containers and also adjustment and/or standardisation of packages, pallets, roll-containers and crates reduce handling of produce in the chain as the produce can move along the chain in the same container, crate or pallet. Standardisation of transportation or handling equipment helps to reduce the number of times an individual container is handled, and reduce mechanical injury in fresh produce by eliminating transfers and fruit handling in the chain (Brecht, 2003).

Van der Vorst et al (2009) mentioned coordinating and simplify logistical decisions in the supply chain by coordinating lot sizes, consolidating goods flows, eliminating human interventions, introducing product standardisation and modularisation as one of the strategies to improve efficiency and effectiveness of supply chain processes. Coordinating logistics activities in a chain by using cross-docking can help reduce storage time of fruits and also number of handling steps in the chain. Kurnia and Johnston (2001) stated reduced damaged products as a result of reduced double handling and reduced expired products as some of the benefits of cross-docking. Unlike in a traditional warehouse where fruits move from receiving to storage then transported later, coordinating logistics activities by using cross docking in which the product moves through distribution centres without storage of product at the result in a reduce storage time and reduced double handling of the product.

A high level of coordination is characterised by establishment of connectivity and transparency, including interconnecting the information systems of the successive partners in the supply chain, standardisation of logistics activities and processes and by using cross-docking, thereby reducing storage time and fruit handling in the chain.

iii. *Appropriateness of packaging and stacking arrangement of batches in the chain*

This indicator assesses stacking and packaging arrangement of fruit at all handling stages in the chain. The assumption is that avoiding over-filling and under-filling by correct fruit configuration, pack size and packaging, and stacking fruit batches at appropriate height and correct density at all handling stages in the chain will reduce mechanical damage that is due to compression injury, vibration injury and abrasion injury, and also enables free circulation of cold air within the stacked fruit batch preventing development of hotspots.

Chonhenchob and Singh (2003) reported that proper packaging and configuration of fruits helps immobilize the fruits within the packaging container and reduces abrasion injury that is due to fruit-to-fruit impact. Containers should not be filled either too loosely or too tightly as loose products may vibrate against others and cause bruising, while over-packing results in compression bruising (Kitinoja and Kader, 2002). Therefore, it is important to correctly packing fruit so as to avoid over-filling and under-filling.

Kader and Rolle (2004) reported that fresh produce must be stacked in a way that enables proper air circulation in order to facilitate removal of heat from the produce as well as to dissipate incoming heat from the atmosphere. Tanner et al (2003) stated that fresh produce should not be densely stacked so that cold air circulation is blocked or stacked high such that it is out of the refrigerated zone as this will expose the produce to ambient air temperatures resulting in development of disorders such as fruit softening. It is therefore important to check if fruit batches are always stacked correctly during at all handling stages in the chain.

The most appropriated handling of fruit in the chain is reflected by fruit batches that are stacked to a height were the batches are not exposed to out or the refrigerated zone and also stacked to a density where there is free air circulation preventing formation of hotspots. Fruit are packaged to correct pack size avoiding under filling and overfilling, preventing compression damage and abrasion damage respectively.

Indicators for Level of integration of quality control and logistics control activities

Quality decisions and logistics decisions differ at each level in the chain and both quality control and logistic control have an influence the quality of the kiwifruit. According to Van der Vorst et al (2005) information on quality of a batch at the beginning of the chain makes it easy to manage product quality throughout all the stages in the supply chain as conditions in the chain can be adjusted to maintain the initial batch quality. Further, Van der Vorst et al (2005) reported that knowing product quality at all stages in the supply chain enables the smooth flow of good with different quality attributes to different logistical distribution channels under different environmental conditions, or to different customers that have different quality demands.

In this study, quality controlled logistics is characterised by integration of two main elements logistics control and quality control by information exchange as logistics decisions rely on information about quality. A higher level of quality controlled logistics is reflected by a use sophisticated methods to predict incidence of fruit defects, exchange of quality information in the chain and flexibility of the delivery systems to match specific consumer requirements. These three indicators are discussed in detail below;

i. *Sophistication in predictions of incidence of fruit defects in the chain*

This indicator is used to assess the criteria upon which predictions on incidence of fruit defects are based on. The assumption is that use of scientific based information, time-dependent quality information, quality decay models and expert knowledge, will result in a more systematic and reliable way of predicating incidence of fruit defects in the chain and doing so, will help to take corrective action before the development of defects.

The above assumption can be supported by literature from Kirkby at al (2004) who reported that management of quality relies on the ability to predict changes in quality. Luning and Marcelis (2009) reported that by using time dependent quality information and quality change models, it is possible to predict product quality in much more detail, enabling control of supply chain processes and direct specific products batches under specific environmental conditions to specific market segments. Luning et al (2009) reported that effective predictions should be supported by knowledge of the mechanisms in product and production processes based on scientific knowledge, having specific, detailed, and actual information, and the ability to use this knowledge and information.

Opara (2009) noted that the interactions between the various components must be understood so that produce quality can be predicted at all stages of the chain. According to Kirkby at al (2004) maturity at harvest, fruit dry matter content and fruit firmness measurements are the most useful variables in formulating predictions about development of physiological disorders such as physiological pit during storage. Clark et al (2004) reported that visible-near infrared spectroscopy measurements made at harvest could be used to identify populations of fruit within a harvest batch that were more prone to storage disorders, such as chilling injury.

A high level criterion to predict incidence of fruit defects is characterised by using time-dependent quality information on fruit status at any given point in the chain, use of quality decay models and scientific expertise. This will result in a systematic way of predicting development of fruit defects in the chain.

ii. *Adequacy of information exchange in the chain*

This indicator assesses the quality of shared information in the chains. The assumption is that exchange of quality information on fruit properties, pre-harvest factors and chain conditions will reduce incidence of fruit defects by using this information to predict incidence of fruit defects, regulate conditions in the chain and make informed logistics decisions that will result in fruits being delivered to the consumer before development of fruit defects. A high level of quality information is characterised by frequent exchange of real-time and quality dependent-information on fruit properties, pre-harvest factors and post-harvest chain conditions that is accurate, timely, credible, complete, relevant, easily accessible, and frequently updated. The information is easily available to all actors in the chain through electronic data interchange (EDI).

Zhou and Benton (2007) argued that there is need to share the right information at the right time in the right format by the right people under the right environment to maximize the benefits of the supply chain as a whole. Lee and Strong (2004) identified the following information attributes as a reflection of high level of quality information; (1) accessibility, which directly reflects data availability, (2) relevancy which is associated with how the information is applied to a specific task, (3) a timeliness dimensions reflecting the creation date of the data, (4) accuracy that represents information that is correct, and (5) completeness which relates to an all-encompassing value allowing a task-at-hand to be addressed. Whipple et al (2002) argued that the information system is perceived useful the information is readily accessible, accurate and relevant. Van der Vorst et al (2002) noted that data timeliness and data applicability are prerequisites when exchanging information.

Therefore, quality of the exchanged information is an important aspect to consider when measuring this indicator. The importance of quality information is also emphasissed in by Luning and Marcelis (2009) who reported that time dependent quality information and quality change models can be used to predict product quality in much more detail, which enables the control of supply chain processes and direct specific products batches under specific environmental conditions to specific market segments.

iii. *Flexibility of the delivery systems*

According to Gunasekaran and Bulent (2007) flexibility can be rightly regarded as a critical factor in any supply chain. Being flexible means having the capability to provide products that meet the individual demands of customers (Gunasekaran and Bulent, 2007). This indicator assesses the ability to change technological conditions in order to support a specific quality level of a given batch such that development of fruit defects is prevented or is minimal in the chain and fruits reach the intended destination at the agreed quality level.

The assumption is that a flexible delivering system will reduce the development of fruit defects in the chain by accordingly adjusting technological conditions to ensure optimum time-temperature and relative humidity conditions required to maintain a specific fruit's quality level. Such a delivering system will direct fruit batches of a specific quality level to specific consumers under specific conditions.

Vigneault et al (2009) recommended that fruit batches be separated according to differing storage and transportation requirements as each fruit quality level or fruit variety may require different temperature and relative humidity conditions. Heterogeneous batches require some level of compromise in selection of the best temperature as several product compatibility factors must be considered. The most important is temperature compatibility as chilling sensitivity differs according to fruit variety and quality status (Brecht, 2003). Another important compatibility factor to be considered is ethylene production and sensitivity to ethylene exposure. Brecht (2003) stated that ripening climacteric fruits such as avocados or bananas should not be stored or transported with fruits such as kiwifruits that might be damaged by ethylene. Therefore, it is important to have a flexible delivery system in which technological conditions such as time-temperature and relative humidity can be easily adjusted at any given time to support a specific fruit quality level that has propensity for development of specific fruit defects.

A higher level of flexibility is characterised by a delivery system is which settings for time-temperature and relative humidity conditions are dynamic and accordingly adjusted to provide optimum conditions that support the homogenous quality level of a given batch preventing development of mainly physiological defects. Beside fruit quality, conditions are also adjusted according to fruit's propensity to develop defects and time-temperature history.

Grid to Assess level of control

After discussiong the indicators for the three sub-elements of quality controlled logistics, is it important to address question is how to assess them. Grids with descriptions of different levels of control; *Low, Medium and High*, are developed. These grid help to assess level of quality controlled logistics in the chain. The assumption is that control activities performed on a higher level will reduce incidence of defects and food losses in fresh agri-produce supply chain. The grid used to assess level of quality controlled logistics is presented in Table 11.

Summary

The research model consisting of four elements; contextual factors, quality controlled logistics, physical process and outcome factors was presented in this chapter. Each element of the research model was discussed and indicators for the respective elements of quality were also presented. The grids that are used to assess performance are also presented.

Table 11: Grids to assess level of quality controlled logistics in fresh agri-produce supply chain

Grid to assess level of quality control				
Indicator	**Assumed mechanism**	**Low level**	**Medium level**	**High level**
Sophistication in product control	Systematic and precise measuring and monitoring methods will result in better detection of defective produce, detection of produce's potential to develop defects.	Only visual inspections and grading are done. No measurement on fruit properties is done and there is delay in taking corrective action	Grading done on every batch and more product properties are measured.	Inspections are done systematically at every critical point and automated inspection systems are used to measure and test product parameters. Statistically underpinned sampling is used at every critical point and corrective action is promptly taken whenever fruit's propensity to develop defects is detected.
Sophistication in monitoring of chain conditions (temperature and relative humidity)	Systematic monitoring of chain conditions and maintenance of measuring equipment will result in better monitoring of temperature and relative humidity conditions.	Monitoring of chain conditions is *Ad hoc* and no documentation is done to keep records of measurements done. Calibration of monitoring equipment is done only when a problem is detected.	Monitoring done regularly but not systematically scheduled. Some form of documentation of monitoring activities is done. Basic monitoring instruments are used. Calibration is done regularly as per scheduled.	Systematic monitoring using precise, accurate, sensitive and reliable sensors or recorders. (E.g. use of time-temperature indicators). Monitoring and measuring equipment is regularly calibrated and there is a clear calibration schedule in place
Adequacy of quality procedures	Well documented handling procedures with assigned responsibilities will result in improved handling of the produce along the chain decreasing incidence of mechanical defects that are due to poor handling	Instructions on handling techniques not clear, precise and not readily available. Instructions are all by word of mouth	Handling procedure are available but not accessible to all those who need them. Procedures not regularly updated to match changes in control systems	Handling procedures are well documented with assigned responsibilities. Procedure manuals are easily accessible to all those that need them. The content is continuously revised to match changes in control system. Visual aids such as charts, or photographs are used to make the procedures more understandable
Sophistication of identifying critical control points	A systematic way that uses scientific evidence to identify and establish critical control points will result in reliable and accurate control points at which incidence of defects can be prevented	Establishment of CCPs is based on historical or commonly available knowledge, not explicitly judged by experts, differs with individual in the chain	Establishments of CCPs based on comparison with regulatory documents, by expert, on regular basis; findings are documented	Scientific expertise and scientific evidence on factors influencing incidence of defects and quality is systematically used to identify the critical control points in the chain

Grid to assess level of logistics control				
Indicator	**Assumed mechanism**	**Low level**	**Medium level**	**High level**
Level of flexibility in inventory issuing system	A flexible inventory issuing system will result in produces batches that are at risk or have high propensity to develop defects being picked for delivery first	Inventory issuing system is standard on all batches and it is based on the duration the product has been in storage (produce's age). FIFO issuing system is used	Inventory issuing system is a bit flexible as it is based on based on produce's age and produce quality. Inventory system such as FIFO, FEFO, or SIRO are used depending of quality and age of produce in storage	Inventory system is flexible and based on time-dependent quality information, quality decay models and prediction of incidence of defects in the chain. Different issuing systems such as HQFO, LQFO and FEFO are used.
Level of coordination of logistics activities	Coordination and standardising transportation, handling equipment, packaging, pallets or crates will reduce number of fruit handling stages in the supply chain and this effectively reduces losses that are due to mechanical damage	Logistics activities are done independent of each other. Crates or pallets of different sizes are used resulting in many handling stages in the chain.	Crates and pallets are standardised and few there are few handling stages in the chain. Co-ordination of logistics activities is centralised to some extent. Few departments making it easy to coordinate activities.	Coordination of logistics activities such as inventory planning and transportation is centralised. Standardisation of packaging and pallets throughout all stages of the chain (e.g. same crates size) resulting in reduced handling stages.
Appropriateness of produce handling in the chain (e.g. packaging, stacking etc.)	Correct fruit configuration, pack size and packaging, and stacking of fruit batches will reduce mechanical damage and also enable free circulation of cold air within the stacked fruit batches preventing development of hotspots	Fruits are packed in correctly packaging material. Fruits are sometimes over-filled or under-filled resulting in many defects. stacking distance is not maintained impeding free air circulation resulting in hot spots	Fruits are packed in correctly packaging material, well protected and under and over-filling is avoided. However, stacking distance is not maintained impeding free air circulation	Fruits are packed in correctly packaging material, well protected and under and over-filling is avoided. Batches are correctly stacked allowing enough air circulation and avoid hot spots.

Grid to assess level of integration of quality control and logistics control activities				
Indicator	**Assumed mechanism**	**Basic level**	**Medium level**	**High level**
Sophistication in predictions of incidence of fruit defects	Use of scientific based information, time-dependent quality information, quality decay models and expert knowledge, will result in a more systematic and reliable way of predicating incidence of fruit defects in the chain	Prediction not reliable and is solely based on historical data and mental models.	Predictions based on historical data, common knowledge and time-temperature indicators. Predictions are not done for a few stages of the chain	Time-dependent quality information on fruit status at any given point in the chain, quality decay models and scientific expertise are used to predict incidence of fruit defects in the chain
Adequacy of information exchange in the chain	Exchange of real time quality information on produce properties and chain conditions will reduce incidence of defects by using this information to take preventative action, regulate chain conditions and to make informed logistics decisions resulting in fruits being delivered to the consumer before development of fruit defects	There is less information exchange in the chain. Information shared is often incomplete and insufficient.	Technology links are in place to enhance information exchanged. Accurate and sufficient information is shared. However, there are delays in exchange of the information making it not reliable to use in decision making	There is frequent exchange of real-time and quality dependent-information on produce properties. Information is accurate, timely, credible, complete, relevant, easily accessible, and frequently updated. The information is easily available to all actors in the chain through electronic data interchange (EDI)
Flexibility of the delivery systems	A flexible delivering system will help reduce the development of fruit defects in the chain by accordingly adjusting technological conditions to maintain a specific fruit's quality level and adjusting inventory issuing system to avoid development of defects	Inventory issuing system is standard in the chain regardless of fruit's condition. Settings for temperature and relative humidity conditions are standard throughout all handling stages	Inventory issuing system in adjusted accordingly to avoid development of defects. Settings for temperature and relative humidity conditions are standard throughout all handling stages	Settings for temperature and relative humidity conditions are dynamic and accordingly adjusted to provide optimum conditions that support the quality level of a given batch and also according to produce's propensity to develop defects. Inventory issuing system in adjusted according to fruit quality, expected shelf life and propensity to develop defects

Chapter 4 CASE STUDY

This chapter gives a detailed description of the unit of analysis, data that was collected and methods of data collection. In order to evaluate the research model presented in Chapter 3 two case studies were conducted. Exploratory case study research strategy was used. According to de Vaus de (2001) the case study method allows for an investigation in a contemporary phenomenon within its real-life context and multiple sources of evidence can be used. Tellis (1997) reported that case studies in their true essence explore and investigate contemporary real-life phenomenon through detailed contextual analysis of a limited number of events or conditions, and their relationships.

Two case studies were carried, one in a banana supply chain in Zimbabwe, and the second in cut flower supply chain in Kenya. The case study in the banana supply chain was conducted in the month of July 2010 and the case study in the cut flower supply chain in Kenya was conducted during the first week of August 2010. Schematic representations of the stages in the two supply chains that were studied is presented are presented in Annex C and Annex D.

4.1 Methods of data collection

To address the issue of validity, triangulation of sources by using multiple data sources is used. Verschuren and Doorewaard (2005) described triangulation as a technique of combining different sources of evidence in a single study. Data collection methods used in this study included interviews, content analysis of documents and databases, and participatory observations. According to Vaus de (2001), interviews provide an opportunity to contextualise survey findings and explore issues of interest in greater detail. Vaus de (2001) further reported that interviews emphasise qualitative analysis and are useful for answering questions regarding what, why, how and, are also ideal for identifying best or unique practices.

Verschuren and Doorewaard (2005) stated that data can be collected either by being a non-participant observer or a participant observer. Direct observation occurs when the investigator makes a site visit to gather data. Participant-observation makes the researcher into an active participant in the events being studied. The technique provides some unusual opportunities for collecting data (Tellis, 1997).

The questionnaire used to collect data is presented in Annex A. The questions were derived from the indicators of the elements of quality controlled logistics presented in the research model. The questionnaires were filled in by the farms managers at all the farms visited. Follow up questions were asked during the tours around the farms. At cut flower farms visited in Kenya, data was collected mainly through interviews and the questionnaire. Participatory observation and document analysis to validate some of the answers to the questionnaire was limited due to limited time as only two hours was spent at each farm and also due privacy policy at these farms. In the banana fruit supply chain, all the three methods were used to collect data as the researcher was granted access to all documents requested and spent more time at the farm. Methods of data collection used are shown in Table 12.

Table 12: Methods of data collections

Method of data collection	**Cut flower supply chain**	**Banana supply chain**
Number of farms visited	5 farms were visited	One farm was visited
Document analysis	Only procedures displayed on walls were analysed	Procedure manuals, standards, production records,
Interviews	8 people were interviewed; Five farm managers at the five farms visited and three experts working in the cut flower supply chain	3 people were interviewed; farm manger, depot manager and grading and packing supervisor
Questionnaires completed	Five questionnaires were completed	Two questionnaires were completed
Participatory observation	Very limited as researcher spent only 2 hours at each farm	Researcher spent 3 weeks at the farm and managed to participate in all handling stages in the chain

Data gathered from the questionnaires (Annex A), interviews and participatory observations are presented in Annex B. Summarised answers to each of the case study are also presented in the results of each case study in the sections below.

4.2 Case Studies Findings

The objective of the cases studies was to evaluate the research model presented in Chapter 3. For each case study, causes of defects in the supply chain are first presented, identified critical control points at which the defects can be prevented or minimised are also presented, and lastly, an assessment of level of quality controlled logistics in the chain is discussed.

Case Study A: Banana Supply Chain (Zimbabwe)

This section presents the findings from the case study conducted at in a banana fruit supply chain in Zimbabwe from 7 July to 30 July 2010. The farm at which the case study was conducted is the leading Banana producer in Zimbabwe. Bananas (*Musa* spp) is a perennial giant herbaceous plant, with roots, rhizome stem or bulb type, and some adventitious roots. They are a staple food for at least 400 million people worldwide (Clendennen et al., 1997). In addition to being a major source of carbohydrates, banana fruits contain high levels of potassium and Vitamin B and C (Sagi et al., 1998). Bananas are grown in Africa, India, Central and South America. Growth temperature should not be lower than 15 °C and the highest temperature should not exceed 35 °C (Robinson, 1996).

Contextual factors

The company produces an average of 800 tonnes a month and of this, 500 tonnes is for local market and 300 tonnes is exported to South Africa. Three varieties, Grand Nain, Williams and Dwarf Cavendish grown at the farm. Of the 500 tonnes sold locally, 70% is sold to informal traders and 30% to formal traders. Bananas have a wide temperature range of between 13 ^{o}C and 30 ^{o}C (Jiang et al., 2002). Under optimum conditions the shelf life of bananas is 10 to 14 days after ripening (Jiang et al., 2002). Other contextual factors in this chain are presented in Table 13.

Table 13: Contextual factors in banana fruit flower supply chain

Contextual factor	**Characteristics**
Product characteristics	• Have a wide optimum temperature range of between 13^{o}C to 25 ^{o}C • Bananas are perishable and have a shelf life of with a vase life of 7 - 12 days under optimum conditions
Process characteristics	• Banana are climacteric fruits and require ethylene to ripe • Main processing stages in the chain include dehanding of the bananas, grading and ripening
Chain characteristics	• About 40% of the bananas produced is exported to South Africa and transportation is by road. • Only one actor is involved as the grower does the transportation and marketing also
Market characteristics	• The bulk of the bananas are sold on the local market where quality requirements are limited. (bananas of all grades are sold at the same price) • Segregation of bananas is according to size, ripeness and defects

Bananas are graded according to size (Extra-large, large and standard/medium) and according to quality based mainly on defects such as bruises into; 2nd large and 2nd standard. Only the Extra-Large grade bananas are exported whilst the rest of the grades are available for the local market. The 2nd large and 2nd standard grades are bananas with moderate to severe peel defects, the 2nd large bananas are large sized bananas but of low quality due to defects and 2nd standard bananas being standard/medium sized bananas of low quality. Defects that affect the banana pulp are classified as critical and bananas with such defects are given away as waste or rejects.

Causes of fruit defects in the chain

During the study, several fruit defects were observed and the causes of these defects were investigated. Mechanical damage in the form of bruises, impact damage, and compression injury were found to be the major defects in this supply chain and the major cause of most of these defects was found to be human handling. Observed defects and their causes are discussed below.

i. Primary production

Major fruit defects observed during this stage are abrasion injury due to improper wooden or string propping. Incidences where props are positioned very close to the fruit bunch causing abrasion injury were observed during the field visit. Cuts resulting from field operations such as bell removal were also observed. Natural damage due to plant genetics was also observed. For example, the banana hands of the Williams variety are too close to each other compared to those of other varieties, causing the fingers to brush against each other leading to abrasion injury.

ii. Harvesting

During the harvesting operations, abrasion and impact injury were found to be the common and these defects were mainly due to human handling. For example, carriers were observed running whilst carrying bunches from the field to the trailer causing damage to the fruit.

iii. Transportation from field to packing shed

Banana bunches are transported in tractor drawn trailers. Bunches are placed on top of plastic cushions and cushions are also placed between bunches to avoid impact damage. However, abrasion injury caused by old petals not removed before loading of new bunches and scarring injury caused by sand that is not removed from the cushions before loading of new bunches were observed. Impact injury caused by banana fingers that are naturally close to each other was also observed.

iv. Dehanding, washing and grading

Cuts, bruises and impact injury are common during this stage. Cuts were found to be common due to human handling during dehanding of bunches. Impact injury due to banana hands being thrown on top of one another in the water trough, abrasion injury due to the banana hands brushing against the edges of the water trough and damage caused by splitting of bananas hands into few fingers being done by hand instead of knives are other defects found to occur at this stage.

v. Packing

Bananas are packed into 3 different types of packaging, bulk bins weighing 340-360kgs when full, plastics crates and boxes weighing 18.5kgs when full. Compression damage resulting from over-filling of bulk bins and incorrect stacking of bulk bins was found to be common cause of defects during the packing stage. Bruises ranging from moderate to critical caused by the arms of the fork lift during palletising of over-filled bulk bins were observed. The edges of the side planks of the wooden bins are another cause of bruises. Bananas on the sides of almost every wooden bulk bin, even those not over-filled were found to have bruises caused by the rough wooden material.

vi. Stacking

Bulk bins are stacked in piles of threes (3 bins x 320kgs) and boxes are stacked 50 boxes per pallet (18kgs X 50 boxes). Defects due to compression injury, especially in overfilled bulk bins, plastic crates or cardboard boxes are common at this stage in the chain. Improper alignment of bulk bins was found to be another cause of defects during stacking. Severe bruises and damage was observed in some bins that were wrongly stacked.

vii. Transportation to other depots

Bananas are transported to other depots using 30 tonne non-refrigerated trucks. The trucks are loaded in the late hours of the day and trucks move during the night. It was noted that the tarpaulin used to cover the bulk bins was causing some bruises on bananas on the top layers as the tarpaulin will be hitting against the bananas due to wind. It was also noted that during transportation, bananas are also bruised as they brush against the sides of the wooden bulk bins due to vibration.

Summary of factors influencing incidence of banana fruit defects

From the causes of defects presented above it can be concluded that human handling is the main factor influencing the incidence of fruit defects in this supply chain and can be prevented or minimised if proper handling procedures are followed at all handling stages in the chain. A schematic representation of the causes of defects in the banana supply chain is presented in Figure 10.

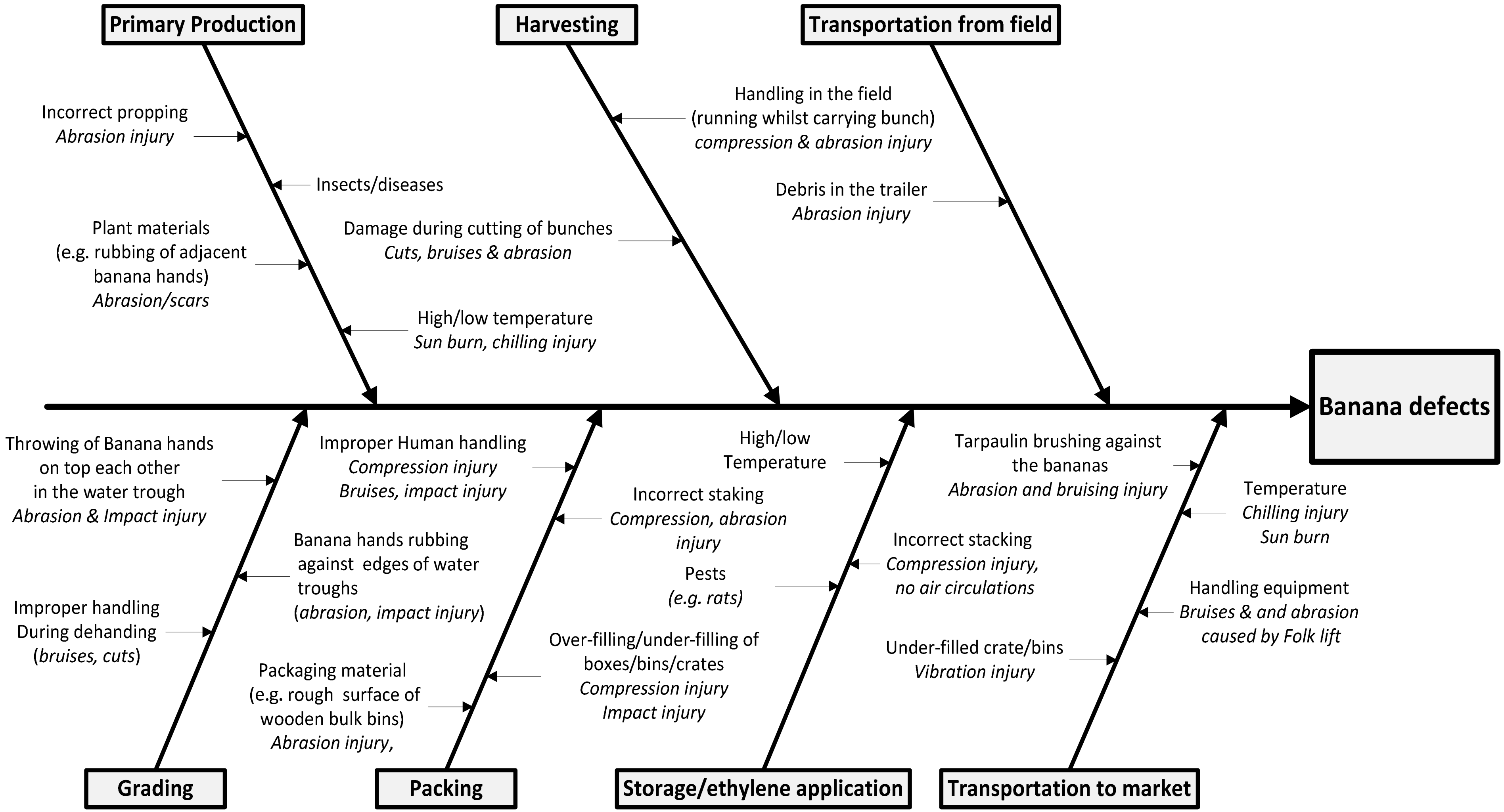


Figure 10: Causes of defects in Banana fruit supply chain

Critical control points at which the defects can be prevented or minimised

For this study, a critical point is defined as a point, step, or procedure at which incidence of mechanical and/or physiological fruit defects is high or has an influence on development of mechanical and/or physiological defects at later stages in the supply chain. Control activities at this point can help to prevent or reduce development of the defects at that particular point and/or at subsequent stages in the chain. These points are key to preventing or minimising incidence of major fruit defects and it is important to identify these points and develop strategies to reduce the development of defects at such points. Discussing with some depot managers and supervisors of the respective stages in this chain, the following points were agreed to be the main critical control points in this supply chain.

i. Primary production stage

During the primary production stage, propping is a critical stage at which close attention is needed and supervision is required. The stage at which propping is done and the quality of propping is also important critical. Propping helps to support banana plants such that they do not fall due to weight of bunches. Props should not be place very close to the bunch to avoid banana hands brushing against the props.

ii. Harvesting stage

Maturity stage at which the bananas are harvested is important as over mature fruits are likely to split during handling and immature fruits do no ripe well. Yanez et al (2004) reported that over mature bananas easily split due to a slight knock or impact injury compared to bananas harvested at full three quarter maturity. Hence, proper age control and identification of correct maturity stage is a critical control point in the banana supply chain. Close supervision is required at this stage to make sure that tagging of bunches in the field is correctly done otherwise, bananas will be harvested at the incorrect maturity stage, either immature or over mature. Knowledge and experience of personnel involved in tagging and harvesting of bananas are important aspects required for visual assessments of fruit maturity.

iii. Packing

Packing is a critical control point at which compression injury due to over-filling of bulk bins, crates or boxes can be reduced. Bulk bins, crate, and boxes should not be filled to the bream of the packaging such that during stacking the top layer of bananas is compressing by the bin, box or crate placed on top layer. Hence, this is a critical control point at which handlers have to adhere to procedures and also close supervision is important to avoid over-filling of bins, crates or boxes.

iv. Storage and ripening stages

Temperature and relative humidity are critical conditions that need to be controlled, especially during storage and artificial ripening. Bananas are prone to chilling injury if exposed to temperatures below 13 ^{o}C and also affected if exposed to high temperatures above 30 ^{o}C. Jiang et al (2002) reported that besides chilling injury, banana fruit stored at low temperature is associated with a decrease in ethylene binding. The ability of tissue to respond to ethylene is greatly reduced resulting in failure to ripen (Jiang et al., 2002). Exposure to temperatures above 30 ^{0}C result can cause the banana pulp to be cooked, tissue becomes watery and translucent whilst the peel is still green (Marchal, 1998). Hence, temperature is an important parameter that should be controlled in the chain. Also, during artificial ripening, temperature at which ethylene is applied is critical for a successful ripening.

Relative humidity is also a critical parameter during artificial ripening of bananas. Ahmad et al (2006), noted that the interaction of ethylene with humidity has a greater effect at higher humidity levels than at lower humidity levels. Ahmad et al (2006) observed that high relative humidity accelerated the ripening of banana fruit during artificial ripening. Low humidity (60 - 65%) increased the water loss which reduced the quality of ripe fruit. Banana ripened at medium (80 - 85%) and high relative humidity (90 - 95%) showed the same quality but better than those at low humidity (60 - 65%). Hence, temperature and relative humidity monitoring and control are critical points that need attention in the chain.

v. Grading

It was agreed that grading cannot be classified as a critical control point but deserves special mention as it is an important element in the banana fruit supply chain. Although development of defects such as mechanical defects cannot be prevented or minimised by the grading process, it is important to be able to detect the defects at this stage of the supply chain so that only defect free fruits reach the consumers. This is essential since while the damage may not be visible during inspection it will appear at the market place resulting in rejection of consignment and loss of product. Hence, grading stage is very important in ensuring that defective fruits are identified and classification is done correctly as to avoid cases of customers returning the product.

Assessment of level quality controlled logistics in the chain

Assessment grid used to judge these levels was presented in Table 14. Judging by the answers to the questionnaire and observations made during participatory observation, level of quality controlled logistics in this banana fruit supply chain can be classified as; level of quality control is *Low*; level of logistics control is *Low* and level of integration of quality control and logistics control activities is *Low/Medium*. Scoring done for each indicator is shown in Table 10. Reason for the scores given are also summarised in Table 10 and extensively presented in the subsequent section.

Table 14: Assessment of level of quality controlled logistics in the chain

GRID TO ASSESS LEVEL OF QUALITY CONTROL		
Indicator	**Scoring**	**Remarks**
Sophistication in product control	2	Grading is done through visual classification of fruits according to size and defects. A banana measuring strip is supposed to be used but is not being used
Sophistication in monitoring of chain conditions	2	Temperature monitoring is done through mercury thermometers. Relative humidity is not measured. A hand held probing thermometer is used to measure temperature of bananas at receiving bay. Measuring instruments are rarely calibrated
Adequacy of quality procedures	1	Quality standards and procedure manuals are not readily available and accessible to all operators such as graders or packers.
Sophistication of identifying critical control points	1	There are no clearly identified critical control points in the chain.
CLASSIFICATION	**LOW**	
GRID TO ASSESS LEVEL OF LOGISTICS CONTROL		
Level of flexibility in inventory issuing system	1	FIFO policy used at the farm but HQFO policy used at other depots as customers first buy the high quality bananas first
Level of coordination of logistics activities	2	Logistics planning, organization and inventory planning is done centrally
Appropriateness of fruit handling in the chain	2	Bananas are segregated into different grades according to quality and size making it easy to handle different market demands and specifications
CLASSIFICATION	**LOW/MEDIUM**	
GRID TO ASSESS LEVEL OF INTEGRATION OF QUALITY CONTROL AND LOGISTICS		
Sophistication in predicting incidence of fruit defects	1	There is no system or mechanism in place to predict incidence of defects in the chain as no objective measurements are done during grading
Adequacy of information exchange in the chain	2	Quality of information exchanged in the chain is good. Estimates on expected tonnage for coming weeks, tonnage harvested, tonnage sold, quality of bananas packed is exchanged
Flexibility of the delivery systems	2	Settings for temperature are accordingly adjusted to provide optimum conditions for the quality level of a given batch. Inventory issuing system is dynamic to a lesser extent and packaging for different markets is different.
CLASSIFICATION	**LOW/MEDIUM**	

Level of Quality Control

i. Sophistication in product control

Grading is done through visual classification of fruits according to size and defects. A banana measuring strip is supposed to be used to verify the grading done but this verification is rarely done. It was observed that the measuring strip is kept in the office a distance away from where grading is done, proof that only visual grading is done and no verification done to check if grading is being done correctly. Some batches that were wrongly classified were noted during the study. This is due to lack of an objective grading system. Besides visual grading, product control is also done through *Ad hoc* visual inspections and no documentation of these inspections is done.

ii. Sophistication in monitoring of chain conditions (temperature and relative humidity)

Temperature monitoring is done through mercury thermometers. A hand held probing thermometer is used to measure temperature of bananas during receipt or during *ad hoc* inspections. During storage and/or ripening, a banana is attached to the probe of a mercury thermometer throughout the storage/ripening duration so as to monitor the temperature of the banana pulp. Hence, temperature control is done using banana pulp temperature not room.

However, the current monitoring and/or control is dependent on automatic thermostats to regulate temperature. Taking into account that these thermometers are not or are rarely calibrated, it becomes a big risk to only rely on these thermometers to monitor temperature. It was noted that calibration of the thermometers was last done in November 2009, making the thermometers not reliable. It was noted that the hand, the handheld probing thermometers have not yet been calibrated since they were purchased ages ago. Only the cold room thermometers are calibrated at *Ad hoc* and whenever a problem is dictated.

It was also noted that in one of the cold rooms at the farm, the probe of the thermometer is very short such that the attached banana is right above the stacks and directly in front of the fans blowing cold air maaking the temperature of this banana not a reliable indicator of the temperature of other fruits stacked at the middle of the room or any other position.

Relative humidity is not being measured or monitored in the chain. The current practice is to keep the floors of the cold room wet during storage and ripening, but the exact value of relative humidity is not known. As reported by Ahmad et al (2006), to attain the best quality ripe fruit banana, relative humidity during artificial ripening must be 90 - 95%. Hence, it is important to measure and/or monitor actual relative humidity rather than just keeping the floor wet.

iii. Adequacy of quality procedures

Quality standards and procedure manuals are not readily available and accessible to all operators such as graders or packers. Although most of the personnel that are in key positions such as supervisors have on average 5 to 10 years experience, there are no procedures available to new personnel and shop floor operators. Considering that the packers are the last persons to handle the fruit, they should know very well the tolerances for quality. Hence, need for well documented procedure manuals, quality standards, and visual aids they can refer to whenever there is need.

At the farm, a copy of standards used for grading is kept in the supervisor's office. Procedure manuals are in the format of a soft copy and also kept on the supervisor's computer. Also, the soft copies of procedure manuals are not up to date to match new procedures that are now in place. For example, in addition to visual assessment of maturity index, use of a caliper has also been incorporated but the manual is yet to be updated to include the procedure of how to use the caliper.

iv. Sophistication of identifying critical control points

There are no clearly identified critical control points (CCPs) in the chain and what is considered CCPs in this chain vary with individuals. Depot managers and supervisors interviewed gave different points they see as critical control points, proof that there are no critical points established in this supply chain.

Level of Logistics Control

i. Level of flexibility in inventory issuing system

The inventory issuing system in use is First-in-First-Out (FIFO) as the first batches to ripen are the ones that are sold first. FIFO seems to be the only one applicable as bananas ripen within 4-5 days. So it is impossible for a fresh batch to ripen 1st before a batch treated earlier. However, of the ripened batch, since the price is standard for all grades, customers first buy the high quality bananas, Ex-large, large and standards grades. The low quality grades, 2nd large and 2nd standard grades are bought later. Hence, the (High-Quality-First-Out) HQFO seems to naturally apply during the selling of the ripened bananas.

ii. Level of coordination of logistics activities

There is good coordination of logistics activities in the supply chain. Logistics planning, organization and inventory planning is done centrally. This makes it is easy to ensure that all activities in the chain are synchronized and to incidences of shortages and over supply of bananas in the market can be avoided. Estimates of expected tonnages are known in advance due to the tagging system used during primary production. Inventory planning, coordination and control are planned using these estimated tonnages.

iii. Appropriateness of fruit handling in the chain

Bananas are segregated into different grades according to quality and size making it easy to handle different market demands and specifications. Bananas are packed into three different packaging types, wooden bulk bins, plastic crates and cardboard boxes. Once packed, the next handling of the fruit is by the customer during unpacking of the banana fruits. This helps to reduce handling of the fruits in the chain and avoids damage that may occur during repacking.

However, it was observed that bananas of different grades and/or different packaging type are not being separated during storage or ripening. This practise is making it difficult to optimise storage and/or ripening conditions. For example, the plastics crates and bulk bins have more air space compared to cardboard boxes resulting in less air circulation in boxes compared to plastics crates or bulk bins. Hence, fruits in cardboard boxes cool slower than fruit in plastics crates and bulk bins. This makes it difficult to have a uniform temperature in the cold room as fruits packaged in cardboard boxes were found to be a degree plus higher than fruits packaged in bulk bins and plastic crates. Ripening is not uniform as fruits in cardboard boxes ripen faster than those in crates and bulk bins. The supervisors reported that this situation makes it difficult to handle the products as such a situation compromises temperature control. It is therefore important to store and/or ripen fruits in different packaging separately.

It was also noted that fruit batches are being stacked very close to each other and in some case distance between stacks was found to be less than 30 centimetres. Such as situation impedes free air circulation resulting in hot spots. Poorly stacked can prevent airflow as the air will follow the path of least resistance, this can result in uneven cooling within a load or room. Temperature measurements were conducted using a handheld probing thermometer in one of the cold rooms/ripening rooms and it was noted that there was great variation in temperature of fruits within the same room. Fruit temperature was found to decrease with increase in distance away from the fans to the door. Pulp temperature of the banana attached to the thermometer probe read 17.3 ^{o}C, and temperature of fruits stacked near the door was about 17.6 ^{o}C (Bottom layer 18 ^{o}C; middle layer 17.6 ^{o}C and top layer 17.5 ^{o}C). Temperature of fruit near the fans (about 1 metre from the fans) was about 19 ^{o}C (bottom layer 19.3 ^{o}C; middle layer 18.9 ^{o}C and top layer 18.8 ^{o}C). This situation can be attributed to the lack of free air circulation due to closeness of the stacks.

Also, fruits are being stacked behind fans blowing cold air, resulting in batches stacked at the corners having a higher temperature than others as cold air is not reaching these corner due to close stacking being done. Two pallets of boxes were place right below the fans and temperature on the fruits these boxes measured 21 ^{o}C.

Level of integration of quality control and logistics control activities

i. Sophistication in predictions of incidence of fruit defects

There is no system or mechanism is in place to predict incidence of fruit defects as no objective measurements are done in the chain. Through experience and events over time, major points at which defects occur become known. There is no systematic system of prediction of defects is used.

ii. Adequacy of information exchange in the chain

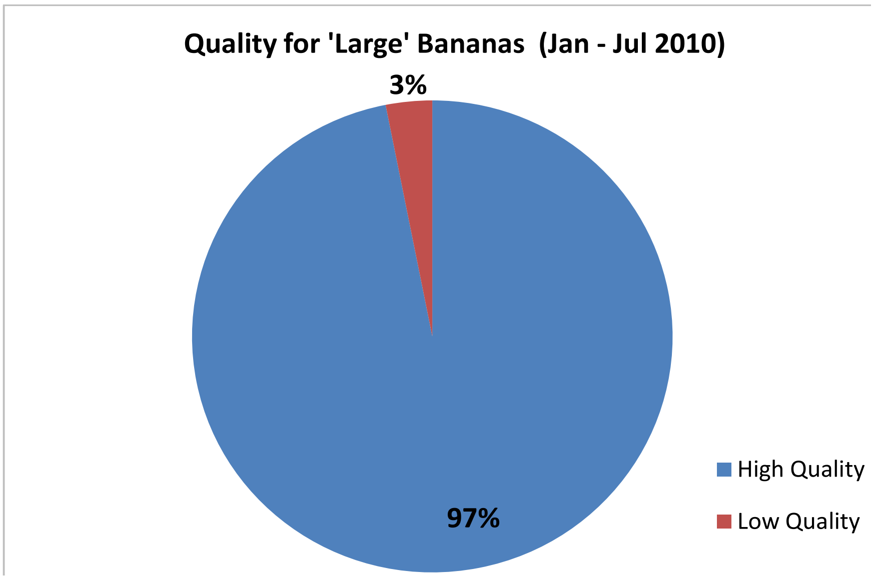
Quality of information exchanged in the chain is satisfactory. Information exchanged in the chain include estimates on expected tonnage for coming weeks, tonnage harvested, tonnage sold, quality of bananas packed. This information is exchanged weekly. There is also exchange of information on expected deliveries between the farm and other depots. Exchange of this information makes inventory planning and control very easy in the chain.

iii. Flexibility of the delivery systems

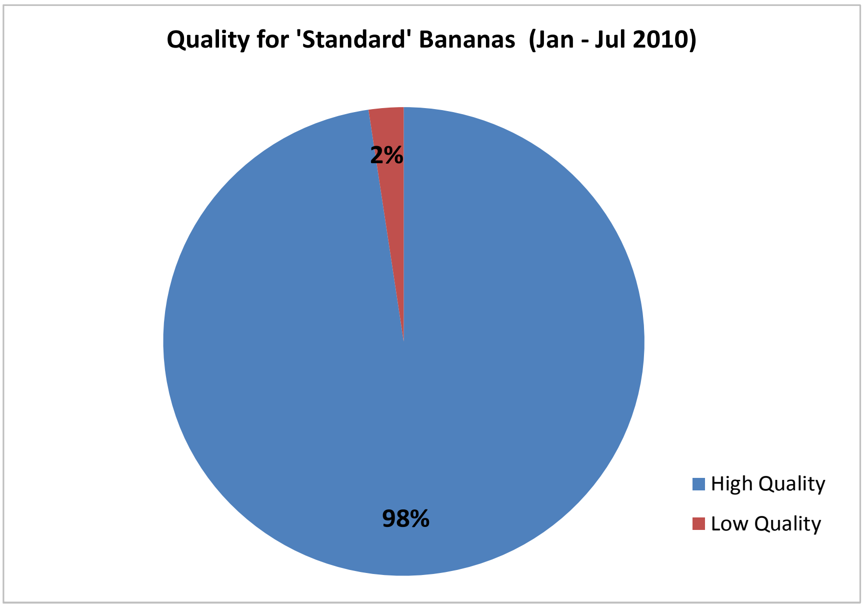
The delivery system is dynamic to a lesser extent. Settings for temperature are accordingly adjusted to provide optimum conditions that support the quality level of a given batch. Inventory issuing system is dynamic to a lesser extent. First-in-First-Out is the main inventory issuing policy although at times other issuing polices are applied.

Outcome factor: Percentage of fruits affected by defects and percentage thrown away due to defects

Quality of bananas processed (Harvested, graded and packed) at the farm from January 2010 to June 2010 was analysed. It was found that 3% (42 073kgs) of large sized bananas were of low quality (2^{nd} large) with moderate to severe peel defects and about 2% (2 135kgs) of standard sized bananas were of low quality (2^{nd} standard) due to moderate to severe peel defects. Causes of these defects were mainly due to mechanical damage. Figure 11 shows the percentages quality of the large sized bananas and the standard sized bananas.



(a)



(b)

Figure 11: Quality of Large and Standard grade bananas (a) Quality of Large grade bananas (b) quality of standard grade bananas. Note: 2nd large and 2nd standard grades are classified as low quality bananas

A small experiment was conducted to find the actual percentage of bananas that are classed as waste due to defects from handling in the chain. Quality of bananas over the three days (12th to 14th of July 2010) was analysed and 47% of the 55 335kgs bananas processed during these days were in grade Ex-large, 36% in grade Large, 7% in grade Standard, 8% in grade 2nd Large and 2% was classified as waste (Figure 12). It can be concluded that 10% (8% 2nd large plus 2% rejects) of bananas processed on these 3 days were affected by defects ranging from moderate to severe.

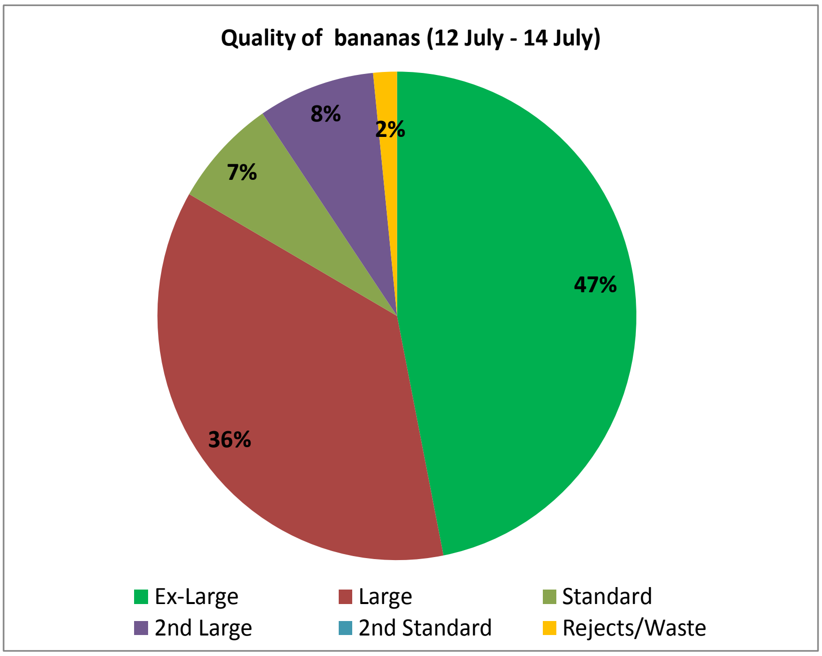


Figure 12: Quality of bananas processed from 12 to 14 July 2010

However, monetary wise, the downgrading of defective fruits into grades 2nd large and 2nd standard was found to have no effect as a flat rate of US$12 per 18kg crate (66 cents/kg) for formal traders and US$8/18kg (44 cents/kg) for informal traders is charged for all grades. Hence, grade Ex-large is sold at the same price as 2nd large or 2nd standard grades. Only the 2% given away as waste can be counted as a loss due to defects.

Case Study B: Cut Flower Supply Chain - Kenya

Case study B was conducted in Kenya from the 3rd to the 6th of August 2010. Data was collected from five growers. The data was collected mainly through the use of a questionnaire and interviews with management of the farms visited.

Kenya's cut-flower industry has been praised as an economic success as it contributed an annual average of US$ 141 million foreign exchange over the period 1996-2005 and about US$ 352 million in 2005 alone (World-Bank, 2005). Kenya exports 35,000 tonnes of cut flowers to Europe, putting it only behind Colombia and Israel for global flower exports, and giving it 60% of the US$165 million African flower trade (World-Bank, 2010). Two thirds of Kenyan cut flowers are marketed through Dutch flower auctions, while the remainder is marketed directly to retailers (Wijnands et al., 2006). Kenya exports 65% of its cut flowers to the Netherlands, 25% to the United Kingdom, 7% to Germany, and 2% to France (World-Bank, 2005).

Contextual factors

Cut flowers are highly perishability and optimum range of 2 to 10 ^{0}C for a storage period of 4–5 days is recommended (Redman et al., 2002). The vase life of flowers is greatly affected by temperature. Reid (2000b) reported that under poor temperature conditions 30% of the potential vase life is lost during transportation. Contextual factors in this chain are presented in Table 15.

Table 15: Contextual factors in cut flower supply chain

Contextual factor	Characteristics
Product characteristics	• Have a small optimum temperature range of between 2^{o}C to 5 ^{o}C • Flowers are highly perishable with a vase life of 5 to 10 days under optimum conditions • Initial variation at harvest is reported to be high
Process characteristics	• Flowers are affected by ethylene and need to be segregated from ethylene producing products • Flowers undergo several processes before transported to the market, pre-cooling, cold storage, grading, grading, bunching, packing, storage, and transport
Chain characteristics	• Most of the flowers are exported to Europe and Asian putting high requirements on chain management • A lot of actors are involved in the chain; grower, freight forwarder, airlines and auction floors
Market characteristics	• There are strict requirements on the market, especially vase life • High level of segregation required, e.g stem size, head size maturity stage and variety

About 90% of flowers produced at all farms visited is exported with the bulk being exported to Netherlands and a considerable amount to Japan. Growers reported that only about 2% of their production is sold on the local market. Strict temperature management is required in the chain and growers and a temperature range between 2^{o}C and 4 ^{0}C is recommended to ensure that their flowers get to the foreign market with acceptable temperature of 14 ^{0}C. These contextual factors put strict requirements on the level of control required in to meet customer requirements.

Causes of defects in the cut flower supply chain

During the study, several defects were reported to occur in this supply chain. The reported defects can be categorised into three groups; those due to mechanical damage, pests and disease and those due to physiological factors such as nutrition and temperature. These defects are discussed below.

i. Mechanical defects

Common defects from mechanical damage were reported to be bruised and torn petals, damaged leaves, and broken stems. Such injuries are undesirable on the market for aesthetic reasons. From the interviews conducted, it was found out that mechanical damage is mainly a problem at grower's stage and minor incidence were reported at the freight forwarder's stage. However, the percentage of flowers rejected or not packed for export due to defects resulting from mechanical damage is small, growers reported that between 0.1 to 1% of flowers harvested daily are downgraded to local sales or thrown away because of defects. Causes of these defects are discussed below.

Harvesting

Mechanical damage is also common during harvesting. Harvesting of roses is manual and bruises occur if too many stems are harvested at once and carried on hands from the field to the buckets. Some growers highlighted that they allow the harvested to carry only 20 stems at a time and others said they allow 40 stems at a time. If the harvested stems are not arranged well when placed on the harvester's hand, petals can be bruised by the leaves of other stems or even prickled by the thorns of other stems.

Over-filling of buckets with the harvested stems is another source of bruises and damage on cut flowers. Overfilling of buckets and placing stems of different sizes in the same bucket can cause injury of the short stems as they will be damaged by the thorns of longer stems.

Transportation from green house to receiving bay/point

All the visited farms use trolleys to transport the buckets and these trolleys are either drawn by tractors or pushed by hand depending on distance. Bruising of flower heads due to vibration during transportation was reported to occur especially if the buckets are under-filled. Some growers use nets to tie round each bunch in the bucket to reduce the vibrations. However, tightened nets are also a source of bruises. These nets need to be loose to prevent squashing of the heads but tight enough not to allow movement of the stems in a bunch.

Grading

Mechanical damage was reported to be also high during grading and sleeving of the flowers. Incidence where too many stems were being sorted on limited space were witnessed during the visits and at one instance, the heads of one stem size were being placed opposite those of another stem size resulting in some heads being right in the thorns of other stems.

Packing

Over-filling of boxes is another cause of mechanical defects in cut flowers. Although the boxes are meant to prevent mechanical damage on the sleeved stems, over-filling of boxes result in compression damage of the flowers heads as they are squashed during stacking. Over-filled boxes were noted during the visits to the freight forwarders. Freight forwarders were complaining that some growers are in a habit of over-filling boxes. This cause compression injury of flowers and also return more heat when boxes are exposed to warm conditions. On average a box should have 240 stems and weight about 12-13kgs. However, freight forwarders reported that sometimes growers will send boxes weighing 19-22kgs.

Loading and unloading of trucks and plane

Incidences of rough handling of boxes during loading and unloading of trucks and airplane were reported during the interviews. Respondents stated that during loading and unloading flowers can be damaged when boxes are pushed or kicked by legs. However, it was reported that such incidences are isolated as once reported, consequences of such actions are serious.

ii. Pests and diseases - Pathological defects

Flowers are very susceptible to diseases, not only because their petals are fragile, but also because the secretions of their nectaries often provide an excellent nutrient supply for even mild pathogens (Elad et al., 2007). All the interviewees pointed out that pests and diseases are a major cause of defects in cut flowers. Losses of up to 15% were reported during wet seasons due diseases such as powdery mildew and downy mildew and botrytis (grey mould). Necrotic lesions or spots are resultant symptoms from the invasion of these pests and diseases. Thrips and aphids were reported to be problematic pests in the cut flowers supply chain. Incidence of defects due to powdery mildew, down mildew and botrytis was said to be seasonal as it is influenced by environmental conditions such as temperature and relative humidity.

iii. Physiological defects

Physiological defects such as gooseneck and bent neck were reported to be common. These defects were said to be common during the pre-harvest stage and various causes were given. Causes of these defects were said to include, environmental factors such as temperature and sunlight, nutrient deficiencies, such as magnesium and pesticide injury.

iv. Genetics

Susceptibility of flowers to bruising was reported to vary with varieties. Varieties; Video, Aneria, and Marina were reported to be very susceptible to damages due to their soft petal, and big heads, while Tropical Azene was reported to be more susceptible to botrytis compared to other varieties. Basically, red roses and white roses were reported to easily suffer damages, for example, the blackening of the petal edges of red roses was reported at all farms visited.

Summary

The factors influencing development and incidence of defects in the cut flower supply can are summaries in the cause-and-effect diagram presented below (Figure 13). Most of the defects are incurred at the farm compared to at the freight forwarder. Few handling defects which are due to improper handing occur at the premises of the freight forwarder.

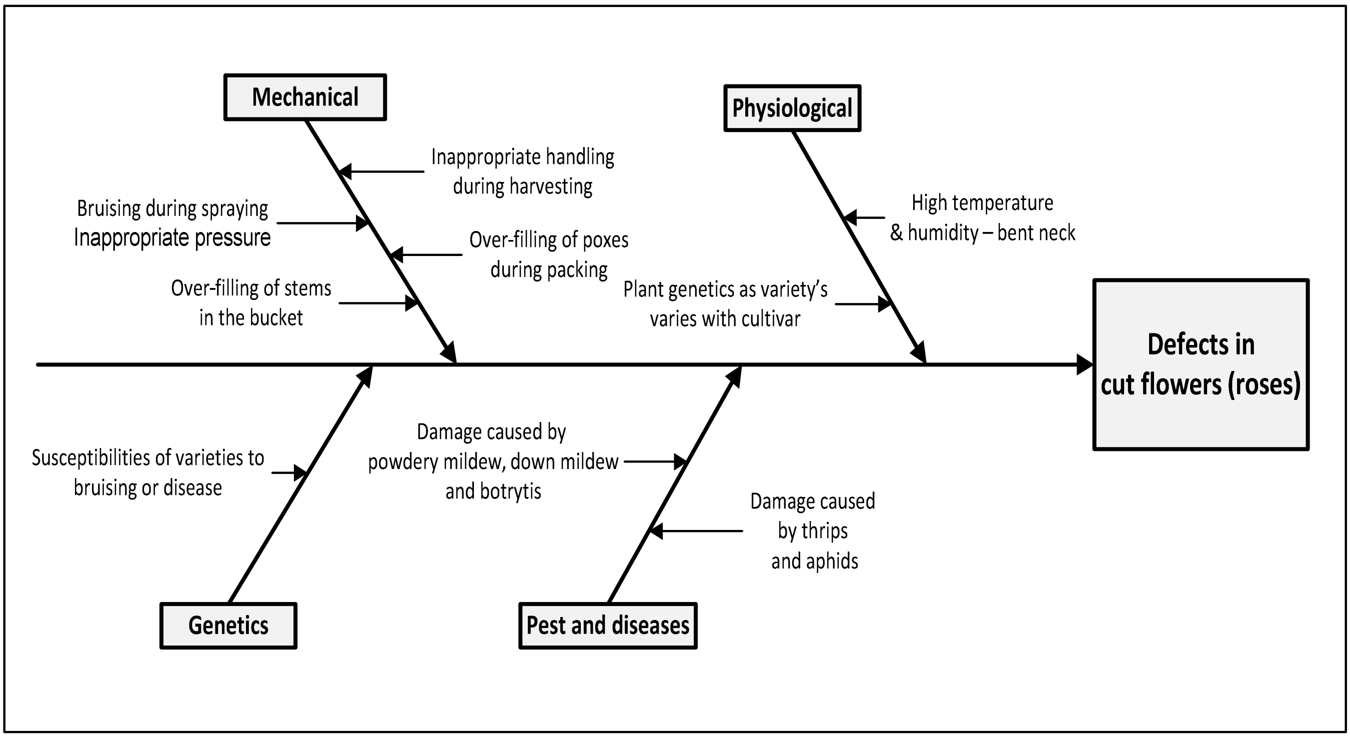


Figure 13: Factors influencing incidence of defects in cut flower supply chain

Influence of temperature

Temperature was reported to be major factor influencing postharvest defects and losses in the cut flower supply chain. It is for that reason effects of temperature control shall be given more attention in assessing the level of control in this chain. Growers visited reported that their greatest fear is to have their consignment destroyed in their export markets because of high temperature and more effort is put to maintain a cold chain.

Most physiological defects and pathological defects are also influenced by temperature and relative humidity. In literature, temperature is reported as the most important postharvest factor in maintaining quality of ornamentals (Celikel et al., 2010, Van Meeteren, 2009). Temperature affects both physiological and physical processes involved in quality loss (Van Meeteren, 2007). Temperature and humidity have a great influence on the vase-life of cut flowers (Reid, 2000a) and has an influence of development of botrytis in cut roses (Elad et al., 2007) and powdery mildew in cut flowers (Mortensen and Gislerød, 2005). Germination of *Botrytis cinerea spores* develop at warm temperature and high relative humidity (Elad et al., 2007, Celikel et al., 2010). According to Redman et al (2002) the spores can germinate only during the period the relative humidity is higher than 98% and both spore germination and hyphal growth also depends on temperature. Experiments by Celikel et al (2010) demonstrated the importance of proper temperature control in the postharvest handling of cut flowers. Hence, temperature is to be given special attention as it has a major influence on postharvest losses in this chain.

Critical control points

From the interviews conducted, it was agreed handling of flowers during harvesting, duration at which flowers are out of storage from the moment the flowers are harvested, and handling of flowers during grading are the most critical control points in this chain. Each point is further described below.

i. *Handling of flowers during harvesting*

It was agreed that the initial point where mechanical damage is inflicted on the plant is in the greenhouse during harvesting. Since harvesting is done manually, cut stem need to be handled with care to avoid the petals being injured. Most of the people interviewed pointed out that this stage is a critical point in their operations. All concurred that proper harvesting techniques should be practised to reduce the percentage defects that occur at this stage. From all the farms visited, average flowers rejected at the receiving bay due to damages during harvesting range from 0.5-2%. Limiting the number of stems carried during harvesting and making sure that all the heads are at the same length, are some of the control mechanisms that can be practised to reduce damage at the point.

ii. *Packing*

Packing of cut flowers was agreed to be a critical control point in the cut flowers supply chain. The correct amount of stems should be placed in the boxes as consequences of over-filling or under-filling the boxes are huge. Under filling can cause abrasion and vibration damage whilst over-filling can result in compression damage of flowers. Besides mechanical damage that can occur, overfilling of boxes can also reduce air spaces in the box impeding proper air circulation during cooling of flowers. This can result in heat being trapped inside the box causing hot spots to develop.

It is worth pointing out that the temperature of the packaging material is also important. Singh et al (2004) stated that placing the pre-cooled flowers in cardboard boxes that have been exposed to the sun or other warm conditions initiates a temperature increase even before the journey has begun. Hence, packing process is a critical control point at which boxes should be packed to the correct weight and correct number of stems, and also the packaging material used should not be warm.

iii. *Duration flowers are out of cold-room from the moment or harvest till loaded into airplane*

Flowers regain heat the moment they are out of cold storage and the duration the flowers are exposed to warm temperature is critical to their vase life. Any point in the chain where flowers are not under cold storage and exposed to room temperature from the moment of harvest until the loaded into the plane was identified by all persons interviewed as a critical control point. In this chain flowers are exposed to room temperature at the following points;

- ✓ Duration from the moment flowers are harvested and put in cold room for pre-cooling
- ✓ Duration flowers are removed from cold storage for grading to the moment they are put back into cold storage
- ✓ Duration from during transportation from cold storage to the airport
- ✓ Duration flowers are out of cold storage until loaded into airplane

All handling employees need to be aware of the sensitivity of the flowers to the time-critical transfers. Also, in literature (Singh et al., 2004, Celikel et al., 2010, Reid, 2000b) these points have been identified as the weakest links in the cut flower postharvest chain.

Assessment of level of quality controlled logistics in the cut flower supply chain

Assessment grid presented in Table 11 is used to assess level of quality controlled logistics in this supply chain. It is also important to note that two intermediary level of control, Low/Medium and Medium/High, are added. These levels help to correctly categorise situations where an actor in the chain satisfies most of the elements of a lower level of control but miss few major elements of the higher level of control, hence in such a scenario, an intermediate level of control is allocated.

Assessment is done for each grower and the results are presented in Table 16. The assessment is based on answers to the questionnaire and interviews conducted during the farms visits (Table 17 and Annex B).

Table 16: Assessment of level of control in the cut flower supply chain

Indicator	Grower (A)	Grower (B)	Grower (C)	Grower (D)	Grower (E)
LEVEL OF QUALITY CONTROL					
Sophistication in product control	3	3	3	3	3
Sophistication in monitoring of chain conditions	3	2	2	2	2
Adequacy of quality procedures	3	3	1	2	3
Sophistication of identifying critical control points	1	1	1	1	1
Level of Quality Control	**Medium/High**	**Medium**	**Low**	**Low/Medium**	**Medium**
LEVEL OF LOGISTICS CONTROL					
Level of flexibility in inventory issuing system	2	2	2	2	2
Level of coordination of logistics activities	3	3	3	3	3
Appropriateness of product handling in the chain	3	3	2	3	3
Level of Logistics Control	**Medium/High**	**Medium/High**	**Medium**	**Medium/High**	**Medium/High**
LEVEL OF INTERGRATION OF QUALITY CONTROL AND LOGISTCIS CONTROL ACTIVITIES					
Sophistication in predictions of incidence of defects	1	1	1	1	1
Adequacy of information exchange in the chain	2	2	2	2	2
Flexibility of the delivery systems	2	2	2	2	2
Level of Quality Controlled Logistics	**Low/Medium**	**Low/Medium**	**Low/Medium**	**Low/Medium**	**Low/Medium**

Table 17: Summarised answers from data gathered from the interviews and questionnaires

Indicators	Grower A	Grower B	Grower C	Grower D	Grower E
LEVEL OF QUALITY CONTROL					
Sophistication in product control	• Flowers classified based on external characteristics, such as stem length, stage of maturity and head size, only. • Inspections are done during harvesting, at the receiving bay, when flowers are removed from the cold room and during packing. Also, every stem is inspected for defects during the grading stage. • There are 11 inspectors present during the grading process	• Flowers classified based on external characteristics, such as stem length, stage of maturity and head size, only. • Inspections are done during harvesting, at the receiving bay, and during grading and packing every stem is inspected for defects • There are 5 inspectors present during the grading process	• Flowers classified based on external characteristics, such as stem length, stage of maturity and head size, only. • Inspections are done during harvesting, at the receiving bay, and during grading and packing every stem is inspected for defects • There are 4 inspectors present during the grading process	• Flowers classified based on external characteristics, such as stem length, stage of maturity and head size, only. • Inspections are done during harvesting, at the receiving bay, and during grading and packing every stem is inspected for defects. • Every stem is inspected for defects during the grading stage. There are 5 inspectors present during the grading process	• Flowers classified based on external characteristics, such as stem length, stage of maturity and head size, only. Every stem is inspected for defects during the grading stage. • Inspections are done during harvesting, at the receiving bay, during grading and packing, and when flowers are loaded into trucks • Grading table re arranged into 3 circles and there is an inspector present at each circle
Sophistication in monitoring of chain conditions	• Temperature and humidity are physically recorded every hour during storage. • Temperature of flowers is also measured at the receiving bay, when flowers are loaded into the truck before transportation to airport. • Room temperature is also monitored in the grading room. • During grading	• Data loggers are used in the chain and temperature is recorded at all stages in the chain. • Temperature of flowers is also measured when flowers are loaded into the truck before transportation to airport. • Relative humidity is not measured.	• Temperature and humidity are physically recorded every hour during storage. • Temperature of flowers is also measured at the receiving bay, when flowers are loaded into the truck before transportation to airport.	• Temperature and humidity are physically recorded every hour during storage. • Temperature of flowers is also measured at the receiving bay, when flowers are loaded into the truck before transportation to airport. • Air curtains are used at all doors into the grading room and into cold rooms to prevent hot air going	• Data loggers are used in the chain and temperature is recorded at all stages in the chain. • Relative humidity is not measured airport. • Temperature of flowers is also measured at the receiving bay, when flowers are loaded into the truck before transportation to airport. • Air curtains are used at all doors into the grading room

	temperature in the grading room is controlled using a water system that is installed on the roof of the building			into the cold room when doors to the cold room are opened	
Adequacy of quality procedures	Procedure manuals are available at all handling stages and during grading, the procedure manuals and standards are available at every working station	Procedure manuals are available at all handling stage in the chain, though not at every working station in the grading room	Manuals and procedures are not displayed at all stages in the chain. Where they are displayed, they are few and incomplete.	Manual are at every working station from the greenhouse up to loading point	Procedure manuals are available at handling stage in the chain, though not at every work station in the grading room
Sophistication of identifying critical control points	• CCPs not defined • No systematic method is used for identifying CCP	• CCPs not defined • No systematic method is used for identifying CCP	• CCPs not defined • No systematic method is used for identifying CCP	• CCPs not defined • No systematic method is used for identifying CCP	• CCPs not defined • No systematic method is used for identifying CCP
LEVEL OF LOGISTICS CONTROL					
Flexibility in inventory issuing system	FIFO issuing policy is used as first harvested flowers are transported to the airport first	FIFO issuing policy is used as first harvested flowers are transported to the airport first.	FIFO issuing policy is used as first harvested flowers are transported to the airport first	FIFO issuing policy is used as first harvested flowers are transported to the airport first FIFO.	FIFO issuing policy is used as first harvested flowers are transported to the airport first
Level of coordination of logistics activities	• All logistics activities are centralised within marketing department • Packing of flowers is done in the cold room to reduce double handling • Flowers are transported early hours of the morning to avoid heat during day light • Flowers are transported in unrefrigerated trucks though sealed	• All logistics activities are centralised within marketing department • Packing of flowers is done in the cold room to reduce double handling • Flowers are transported early hours of the morning to avoid heat during day light • Flowers are used to transport flowers providing optimum conditions	• All logistics activities are centralised within marketing department • Packing of flowers is done in the cold room to reduce double handling • Flowers are transported early hours of the morning to avoid heat during day light • Flowers are transported in unrefrigerated trucks though sealed	• All logistics activities are centralised within marketing department • Packing of flowers is done in the cold room to reduce double handling • Flowers are transported early hours of the morning to avoid heat during day light • Refrigerated trucks are used to transport flowers providing optimum conditions	• All logistics activities are centralised within marketing department • Packing of flowers is done in the cold room to reduce double handling • Flowers are transported early hours of the morning to avoid heat during day light • Refrigerated trucks are used to transport flowers providing optimum conditions
Appropriateness of produce handling in	• Stems are carried on hands during harvesting	• Harvesting basket designed to reduce	• Stems carried on hands during harvesting	• Stems carried on hands during harvesting	• Stems carried on hands during harvesting

the chain	• Stacking Packing is done in a way that allows for free circulation, during cooling	bruising during harvesting are used • Incidences of over-filled boxes from this grower were reported by the freight forwarder handling this grower's flowers at the airport	• Packing is done in a way that allows for free circulation, during cooling	• Packing is done in a way that allows for free circulation, during cooling	• Packing is done in a way that allows for free circulation, during cooling • Racks in one of the cold rooms are constructed in the wrong way resulting in boxes or flower buckets blocking circulation of cold air
LEVEL OF INTEGRATION OF QUALITY CONTROL AND LOGISTICS CONTROL ACTIVITIES					
Sophistication in predictions of incidence of fruit defects	There is no system or mechanism in place to predict incidence of defects in the chain.	There is no system or mechanism in place to predict incidence of defects in the chain.	There is no system or mechanism in place to predict incidence of defects in the chain.	There is no system or mechanism in place to predict incidence of defects in the chain.	There is no system or mechanism in place to predict incidence of defects in the chain.
Adequacy of information exchange in the chain	• Information is exchanged between supervisors of respective stages in the chain, with clients and freight forwarders. • The information is mainly for control purposes and to meet customer specifications. • Exchanged information includes quantity and quality of flowers exported, amount of defective flowers	• Information is exchanged between supervisors of respective stages in the chain, with clients and freight forwarders. • The information is mainly for control purposes and to meet customer specifications. • Exchanged information includes quantity and quality of flowers exported, amount of defective flowers	• Information is exchanged between supervisors of respective stages in the chain, with clients and freight forwarders. • The information is mainly for control purposes and to meet customer specifications. • Exchanged information includes quantity and quality of flowers exported, amount of defective flowers	• Information is exchanged between supervisors of respective stages in the chain, with clients and freight forwarders. • The information is mainly for control purposes and to meet customer specifications. • Exchanged information includes quantity and quality of flowers exported, amount of defective flowers	• Information is exchanged between supervisors of respective stages in the chain, with clients and freight forwarders. • The information is mainly for control purposes and to meet customer specifications. • Exchanged information includes quantity and quality of flowers exported, amount of defects that occurred in the chain
Flexibility of the delivery systems	Settings for temperature at all the stages in the chain are standard irrespective of quality. Inventory issuing system is always FIFO. Flowers are segregated accruing to specific market requirements making it easy to handle in the chain	Settings for temperature at all the stages in the chain are standard irrespective of quality. Inventory issuing system is always FIFO. Flowers are segregated accruing to specific market requirements making it easy to handle in the chain	Settings for temperature at all the stages in the chain are standard irrespective of quality. Inventory issuing system is always FIFO. Flowers are segregated accruing to specific market requirements making it easy to handle in the chain	Settings for temperature at all the stages in the chain are standard irrespective of quality. Inventory issuing system is always FIFO. Flowers are segregated accruing to specific market requirements making it easy to handle in the chain	Settings for temperature at all the stages in the chain are standard irrespective of quality. Inventory issuing system is always FIFO. Flowers are segregated accruing to specific market requirements making it easy to handle in the chain

Outcome factor: Percentage of flower affected by defects and percentage thrown away due to defects

Unlike in the banana fruit supply chain where the researcher was able to quantify percentage of fruits affected by defects and that thrown away as waste, this was impossible in the cut flower supply chain due to limited time the researcher had. However, all growers interviewed stated that about 4% to 5% of their daily production is downgraded due to defects and between 1 and 2% is thrown away because of the defects. These figures were reported to vary with season as some growers reported losses of up to 15% during wet season as a result disease and insect damage. The impact of defects seems to have great repercussions on the quality of cut flowers. Van der Hulst (2004) reported that a minor quality remark by quality controllers at the auction floor can lead to a decrease in price of 5-10%. Two minor remarks, or one major remark, can lead to a decrease in price of 20-50%.

4.3 Summary of results

Results from the two case studies show that level of quality controlled logistics is higher in the cut flower supply chain as compared to that in the banana supply chain. In the cut flower supply chain, the best level of control is in the sub-element logistics control which is *Medium/High* for all growers, followed by quality control, and the lowest is in level of integration of quality control and logistics. The results for the banana fruit supply chain show lowest level of control in the sub-element quality control and level of logistics control and level of integration of quality control and logistics control activites are judged the same, *Low/Medium*. Indicators, *sophistication of identifying critical control points* and *sophistication in predictions of incidence of defects* scored low in both supply chains contributed to low level of control in the sub-elements quality control and integration of quality control and logistics control respectively.

A close look at the contextual factors of the two supply chains presented in Table 13 and 15 shows that the contextual factors in the cut flowers supply chain are more complex compared to those in the banana fruit supply chain. Flowers are more perishable as compared to banana fruits and they have a shorter vase life of 7 – 10 days compared to the shelf life of banana that is between 10 and 12 days under optimum conditions. The bulk of produced bananas are sold on the local market where customer requirements are less strict as compared to cut flower those for the cut flowers.

4.4 Discussion

From the results it can be concluded that there is better level of control in the cut flower supply chain than in the banana fruit supply chain. The reason for higher level of quality controlled logistics in the cut flower suply chain as compared to that in the banana fruit supply chain can be attributed to fact that flowers are more perishable and delicate than bananas, hence more control is required in the cut flower supply chain. For example, the optimum temperature range for flowers is very small 2 to 4 ^{o}C as compared to banana whose optimum range is 13 ^{o}C to 25 ^{o}C depending on variety. This alone puts a lot of stringent control requirements on the cut flowers supply chain.

The impact of defects seems to have great repercussions in the cut flower supply chain than in the banana fruit supply chain. A few bruises on the banana's skin will not render it unfit for consumption but a few bruises on the petals of the flowers can render them undesirable on the market for aesthetic reasons. Van der Hulst (2004) reported that a minor quality remark by quality controllers at the auction floor can lead to a decrease in price of 5-10%. Two minor remarks, or one major remark, can lead to a decrease in price of 20-50%.

In conclusion, it can be said that the results from the case studies proved that a higher level of quality controlled logistics is required to reduce incidence of defects in fresh agri-produce chains that have complex contextual factors as compared to the chain with less complex contextual factors. These results are in line with findings of Van der Spiegel et al (2003) who reported that contextual factors have an influence level of control required to realise the desired quality performance. The diversity in contextual factors can help explain why the performance of quality systems differs (Van der Spiegel et al., 2003).

Lack of *sophistication in identifying critical control points* and lack of *sophistication in predictions of incidence of defects* can be said to be the factors hindering achievement of a higher level of control in both chains. Both chains scored low in these two indicators. Therefore, there is need for the two supply chain to improve on identification of critical control points and also have predictive models in place that can help them to prevent anticipated incidence of defects at predefined points in the chain.

CHAPTER 5 ASSESSMENT OF THE RESEARCH MODEL

This study is the great step towards developing a holistic tool/model that can be used to assess level of quality controlled logistics control in fresh agri-food supply chains. Based on the two case studies in the banana supply chain and cut flower supply chain, the quality controlled logistics model developed in this study is found to have potential in measuring level of control and also to help minimise loses/wastage in fresh agri-food supply chains. A reflection of the conceptual model and research model in relation to the results is discussed in thsi sections. Suggestions on areas of improvement are given and the hypothesis is evaluated last.

5.1 A reflection on the Conceptual framework

The conceptual model used was development from an extensive literature study and all aspects that are important to the study were covered. Literature on causes of defects in fresh agri-produce supply chains, with special mention being on tropical fruits, literature on quality control, logistics control and literature on quality controlled logistics was all used to develop the conceptual model. The developed conceptual model illustrates causes of pre-harvest and post-harvest defects in fresh agri-produce supply chains and critical control points at which the incidence of these defects can be prevented of minimised. Information that is required to control the incidence of these defects is also presented in the conceptual model. Quality control and logistics control factors that can help reduce the defects at the identified critical control points is also given in the model.

Critically analysing the conceptual model in relation to the result from the two case studies, it can be concluded that the conceptual model developed is valid and relevant to the problem situation and can be used to help solve the problem. All elements of the conceptual were found to be useful.

5.2 A reflection of the Research Model

Based on these two case studies it can be concluded that the research model developed in this study have the potential to be used to assess level of quality controlled logistics in fresh agri-produce supply chain and also to provide a solutions on how to minimise food losses/waste in these supply chains.

The research model was constructed based on the conceptual model. All the four elements of the research model were derived from the conceptual model making it relevent to the problem and aslo valid. However, there is need to improve on some areas as some weaknesses where observed during data collections and assessing of level of quality controlled logistics in the two supply chains. Improvements that can be done on the research model are discussed below.

Indicators

This is the major weakness fo the reaserch model. From the asssessment of level of control for each of the sub-elements of quality controlled logistics it was observed that the indicators used are at a higher level and too general making it difficult to score. Critically assessing the research model, it can be said that not all aspects of the conceptual model are used in the research model. There is need to have indicators that are more specific and clear for each sub-element so that all the aspects of the conceptual model are represented. The generalisation of the indicators made it difficult to score using the grid of assesment developed. Hence, there is need to revisit the model and include all aspects of the conceptual model and have more specific indicators for each sub-elements of quality controlled logistics. This will make the reseach model more reliable and applicable in any fresh agri-produce supply chain.

Outcome factors

The outcome factors used in the reseach model are relevent and valid. However, there is need to have include more performance indicators such as finacial losses due to defects. From the case study it was noted that percentage produce loss or waste due to defects if expressed in finacial losses, can be more relevent. For example, only in the banana fruit supply chain if the 8% defective fruits are to be dold at a lesser price than good quality fruit, income lost can be high. Fro example, Van der Hulst (2004) reported that in cut flowers, a minor quality remark by quality controllers at the auction floor can lead to a 5-10% decrease in price and two minor remarks, or one major remark can lead to a 20-50% decrease in price at the auction flower. Hence, expressing the outcome factor/performance indicator in financial terms will make the research model more reliable, relevant and easier to relate level of quality controlled logistics and food losses in the chain.

5.3 Evaluation of the Hypothesis

After evaluating the this study as a whole, the hypothesis; *A high level of control quality controlled logistics which is characterised by the integration of quality control and logistics control will result in less defective produce and minimal losses and waste in the fresh agri-produce supply chain through use of product quality information and predictive models to direct logistics activities,* is be accepted.

Results of the case studies conducted show that one of the bottlenecks to achieving a higher level of control in the two supply chain studied is lack of a way to predict incidence of defects in these chain. Being able to anticipate, especially the development of physiological defects can help take corrective action that can minimise losses due to these defects. Therefore, the hypothesis holds.

However, comparing the results of the two case studies it can be seen that a high level of control is not always required in all to reduce incidence of defects in all agri-supply chain. The results prove that the complexity of the product involved had an influence of the level of control required to realise the required percentage of defects. In this study, it is shown that a higher level of control is required to reduce incidence of defects in the cut flower supply chain as compared to level of control required in the banana fruit supply chain. This can be attributed to perishability and delicacy of cut flowers compared to bananas. Hence, control level required is also determined by the complexity of contextual factors in a given supply chain. The higher the complexity of contextual factors in a given supply chain, the higher the level of control required to reduce losses or waste.

5.4 Recommendations for future research

Based on the two case studies in the banana supply chain and cut flower supply chain, the quality controlled logistics model developed in this study is found to have potential in measuring level of control and also to help minimise loses/wastage in fresh agri-food supply chains. More studies need to be done to make the model more generic and complete. Three areas for further study are suggested;

- Need to investigate in depth how contextual factors of fresh agri-produce supply chains are influence the level of quality controlled logistics.
- To consider more outcome factors such as costs and efficiency
- To review the indicators and make them more specific, especially those under logistics control in the model.

CHAPTER 6 BOTTLENECKS AND ALTERNATIVE SOLUTIONS

This chapter aims to evaluate data collected from field work and the assessed levels of control. A review of this data will enable identification of weaknesses in the control system that need to be considered for improvement. Alternative solutions to the bottleneck are also presented in this chapter.

6.1 Bottlenecks

A bottleneck is defined as any factor that limits or restricts complete adherence to a system or guideline (Gilling et al., 2001). In this study bottlenecks are factors that are impeding achieving of a higher level of quality controlled logistics resulting in high incidence of defects. The bottlenecks in the two chains are discussed below.

a. Lack of established critical control points in the chain

There are no clear and systematic identification of critical control points in the two chains. Points, processes or procedure considered critical in this chain varied with individuals interviewed, even individuals from the same farm. This clearly shows that there are not establish critical control points in the chain. Hence, control is either *ad hoc* or historical data and experience are the basis of control activities being practiced in the chain. This can result in some major critical points being over looked in the chain.

b. Lack of an objective grading system

In the two chains studied, only subjective grading is done. Cut flowers are classified after harvest based on their external characteristics, such as stem length, stage of maturity, flower size and foliage quality. In bananas, also the external characteristics such as size and bruises are considered. It is important to note that the internal quality of flowers, such as the vase life and shelf life in bananas have not been incorporated into cut flower and banana grading standards. Because of visual or subjective grading being practised in these chains, it becomes difficult to have preventative measures that are specific for the anticipated defects for each batch are there are no objective measurements done on produce attributes.

6.2 Alternative solutions

This section is meant to give alternative solutions that can be used to overcome the bottlenecks presented in the early section. Alternative solutions provides suggestions on how to overcome the barriers that have been presented and achieve a better level of control where there is minimum incidence of fruit defects and subsequently, losses due to defects in the supply chain studied. These alternative solutions can be implemented when level of control is unsatisfactory, that is, when percentage incidences of defects and/or percentage of produce thrown away as waste due to defect is unacceptable (Figure 14).

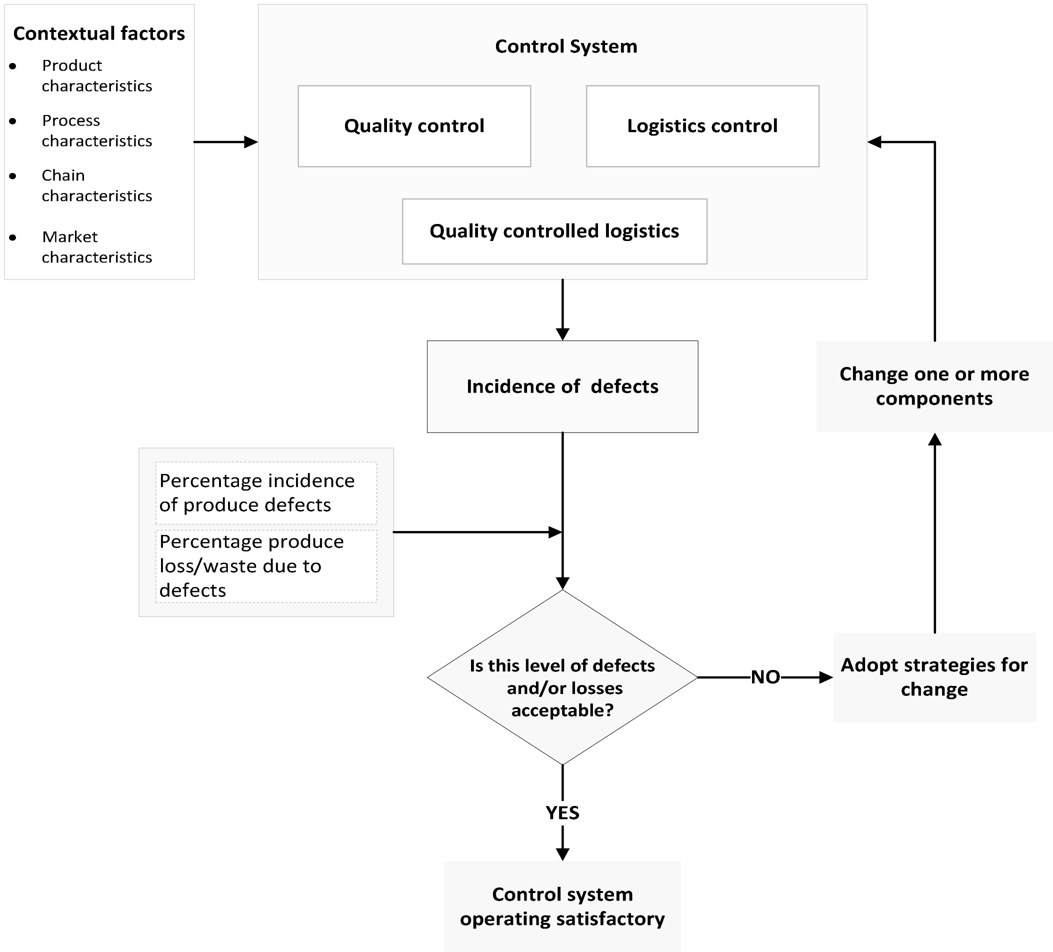


Figure 14: Managing incidence of defects in fresh produce supply chain (own illustration)

Alternative solutions that can be adopted to circumvent the bottlenecks and attain the highest levels of control as presented below;

Solution 1: Having objective grading systems

Computer vision systems have been used increasingly in the horticultural industry for the objective assessment of product quality features. Computer vision encloses the capturing, processing and analysis of two-dimensional images (Brosnan and Sun, 2004). According to Brosnan and Sun (2002b) computer vision can expand the scope of product inspection for evaluating attributes not perceptible to the human eye. Timmermans (1998) reported that computer vision has been used for such tasks as shape classification, defect detection, quality grading and variety classification in fresh horticultural produce. According to Brosnan and Sun (2004) computer vision systems can be used to determine the appearance; size, shape, colour and presence of blemishes in fresh agricultural produce.

Use of computer vision as a means of determining the vase life of cut flowers was examined by Brosnan and Sun (2002b). In this study, the use of computer vision as a method of evaluating cut flower vase life. In their studies Brosnan and Sun (2002b) colour and shape images were captured using computer. The experimental results show that colour assessment by the computer vision system can be also used to detect defects such as bruises in cut flowers. Objective grading systems such as the use of colour vision computer systems will only not help detect defects in the early stages in the chain, but information from such objective grading systems can also be used to predict development of anticipated defects basing on the objectively measured produce properties in the early stages of the supply chain. This will help reduce incidence of produce defects, especially physiological defects.

In et al (2009) highlighted the need of objective grading systems to measure internal quality of flowers which include vase life. Being able to measure internal quality of fresh agri-produce will make it easy to develop preventative measured and also to take correction action and adjusted chain conditions to minimise incidence of defects and losses of produce. Therefore, an objective quality classification system that used computer visions can help detect defects and also provide information for predictive modelling and allow for corrective action to be taken before development of defects.

Solution 2: Having a systematic way to identify critical control points

In this study, it can be said that besides influence of contextual factors, reducing the incidence of defects and food loss in the fresh agri-produce supply chains relies on the achieving a higher level of quality controlled logistics at identified critical control points in the supply chains. Therefore, there identified CCPs should be clear, well defined and identified in a systematic way. The importance of having effective CCPs that are systematically identified is stated in Dome´nech et al (2008). Dome´nech et al (2008) reported that it is important to have a method available to estimate the effectiveness of selected CCPs.

Dome´nech et al (2008) put forward a method to assess the effectiveness of the critical control points based on the consideration of the performance of the couple control-monitoring system. Dome´nech et al (2008) stated that a critical control point (CCP) should consist of two basic elements; the control system itself that implements the control measures and the monitoring system. Elements of a critical control point as described by are shown in Figure 15. It should be point out that this proposed model was developed in relation of guaranteeing food safety, however, it can be adapted develop a systematic way of identifying CCPs at which incidence of defects in fresh agri-produce can be reduce.

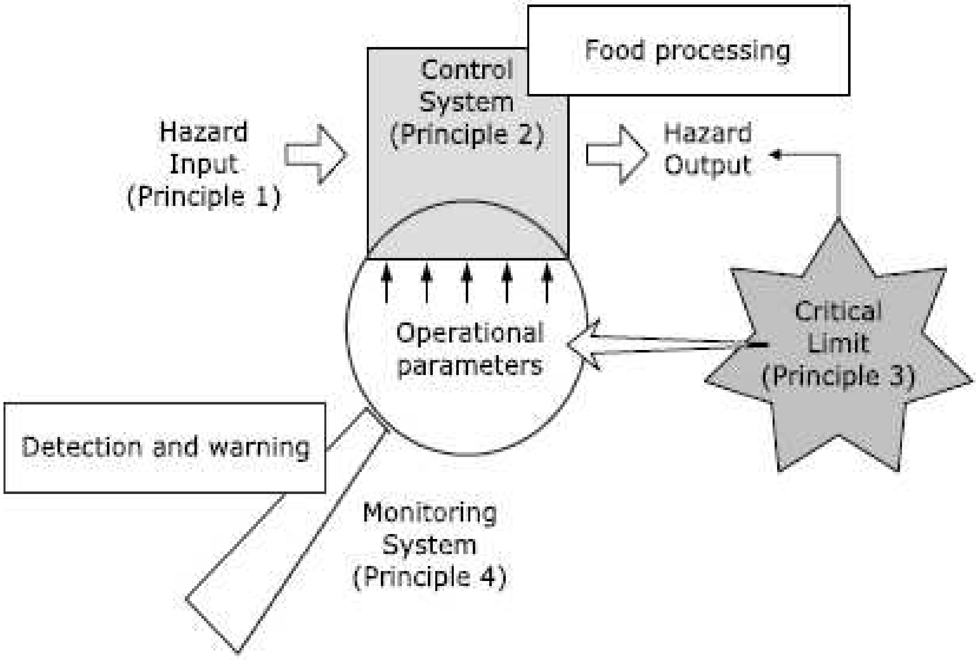


Figure 15: Important elements of a critical control point

A critical control point (CCP) is defined as a step in the flow diagram of the food processing process, at which control measures can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level. The model put forward by (Dome´nech et al., 2008) to systematically identify critical control points consists of four principles as shown in Figure 15. Each principle is briefly described below.

Principle 1: This principle involves hazard analysis to identify all hazards that may be reasonably expected to occur at each step of the food chain. Dome´nech et al (2008) defined a hazard as a biological, chemical or physical agent that is reasonably likely to cause illness or injury in the absence of its control. In this case, hazards can be taken as biological, chemical or physical agent that is reasonably likely to induce development of defects and cause damage of produce.

Principle 2: Consists of identification of hazards. This step is described to be critical. Dome´nech et al (2008) reported that complete and accurate determination of CCPs is fundamental to controlling food safety hazards. If a hazard has been identified at a step where control is necessary for safety, and no control measure exists at that step, or any other, then the process should be modified at that step, or at any earlier or later step, to include a control measure.

Principle 3: Critical limits must be specified for each CCP. Dome´nech et al (2008) defined a critical limit as a maximum and/or minimum value to which a biological, chemical or physical parameter must be controlled at a CCP to prevent, eliminate or reduce to an acceptable level the occurrence of a food safety hazard. Critical limits must be easy to monitor either by measurement or observation and must be scientifically and/ or regulatory based (Dome´nech et al., 2008)

Principle 4: Involves monitoring when the control system fails to meet the critical limit. In such a case, Dome´nech et al (2008) suggested that it is required to establish monitoring procedures. A monitoring system consist of the scheduled measurement or observation of a control measure at a CCP relative to its critical limits (Dome´nech et al., 2008). A monitoring system is also used to determine when there is loss of control.

Solution 3: Having easily accessible procedure manuals and standards

According to Opara (2009), if properly developed and enforced, quality standards are an essential tool of quality assurance in fresh produce supply chain, and they provide a common language for trade among growers, handlers, processors, exporters and importers. The first step for quality assurance is to develop procedures to control the product quality at different stages of production, handling, and packaging (Brown et al., 1993). Opara (2009) further stated that for quality control to be successful, product specifications should include the relevant quality factors or characteristic attributes, and delineated criteria with definitions and descriptions. Visual aids such as colour charts, models, diagrams, and photographs are used whenever possible (Martinez-Romero et al., 2004). Specifications must be understood easily, simple, precise and practicable, using the measuring techniques available at any other stage in the supply chain.

Brown et al (1993) noted that provision of instructions that are easily understandable by the floor shop operators is essential to ensure that fruit damage during fruit handling is minimised. Opara (2009) also reported that handling and quality procedures must be easily accessible, understood easily, simple, and precise. This is supported by Martinez-Romero et al (2004) who also stated that there is a need for provisions of simple and precise instructions on proper fruit handling techniques to employees in order to reduce fruit damage during fruit handling operations in the chain.

6.3 Judgement of solutions

All the three alternative solutions proposed can help achieve a higer level of quaality controlled logistics and reduce incidence of defects and food losses in fresh agri-produce suply chains. The best combination of solutions that can be implemented are given in this section. The solutions are judged using the based on following criteria: (a) Effectiveness to reduce incidence of defects in the chain, (b) applicability (c) cost, and

Figure 16: Criteria used to judge alternative solutions

Solution	Effectiveness in reducing defects	Applicability	Associated costs
Solution 1	Limited as it only helps to identify defects	Difficult to implement as it is time consuming at each stem have to be assessed one by one	Equipment required is expensive
Solution 2	Effective as CCP are identified	Easy to implement	Limited costs is involved
Solution 3	Effective to some extent as procedures will not guarantee compliance	Easy to implement	Limited costs is involved

From the comparison in Table 26 is can be concluded that solution 2 and solution 3 are the best alternation solution that can be implemented to achieve a high level of quality controlled logistics and reduce incidence if defects and food losses in agri-produce supply chains.

CHAPTER 7 EVALUATION

In this chapter relevance of each phase of this research to achieving the set objectives is evaluated. The main objective of the research was to develop and evaluate a quality controlled logistics model that can be used to prevent or minimise losses or wastage that are a result of incidence of mechanical and physiological defects at identified critical control points in the fresh agri-produce supply chain.

Evaluation of theory analysis

The literature and models used in this study were carefully selected from reliable and valid scientific articles. The presented theory clearly gives an insight into factors causing incidence of mechanical and physiological defects in agri-food supply chains. Both managerial and technological theory is presented giving a balance to the techno-managerial approach used in this research. However, it took considerable time to the literature presented in Chapter 2.

Research model and indicators

Exhaustive literature analysis done in the Chapter 2 was the backbone of the development of the research model used in this study. All elements of the research model were derived from literature analysis making the research model reliable and valid as it was constructed from a rich theory analysis. The developing of the research model was the most difficult stage in this study. Great understanding, creativity and critical thinking were all required to develop the research model and to operationalise it. Critical thinking was required to find relevant and valid indicators that are supported by literature. However, there is need to critically analyse the indicators used in this study. More specific indicators are required to make the research model more generic and applicable to all fresh agri-produce supply chains.

Research design and analysis

To ensure validity of the research, triangulation was employed during data gathering. Document analysis, interviews and direct observations techniques were used. This helped to give more weight to the data that was used in analysis and classification of level of control in this research. The design of the research model required a lot of time of the total research time. However, it was impossible to use the participatory observation technique in the cut flower supply chain as there was no enough time. Hence, most data used to judge level of control in the cut flower supply chain is from interviews only.

Evaluation of the researcher

This study was interesting and also an eye opener to me as a researcher. It was interesting to relate the knowledge I gained from literature search and the actual practice in the field as observed during data collection. Having previously worked in the quality assurance field, it was not difficult to understand the concept used in this study. However, balancing the managerial and technological aspect of this research, techno-managerial approach, was a challenge but I believe I managed to do justice in the end. The most challenging part of this research was operationalising the research model, especially finding the most suitable indicators. Also, the translation of scores in into levels of control was challenging. However, I found joy in doing this research and given the opportunity, it will be a privilege for me to continue with this work as I feel more still need to be done.

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Annex A Questionnaire

This questionnaire is used to gather information that will be used to judge level of quality control, logistics control and quality controlled logistics being practiced in the respective supply chains. The questionnaire consists of five parts; assessment of contextual factors, assessment of performance indicators, assessment of logistics control, assessment of quality control, and assessment of quality controlled logistics.

A. Assessment of contextual factors

Contextual factors are inputs to the research model and put requirements on the control system and have influence on the performance of the system. The assumption is that a high complexity in contextual factors results in high percentage of fruit defects and high percentage of fruit loss in the chain, hence, a high level of quality control, logistics control and/or quality controlled logistics is required to minimise the influence of high complexity of contextual factors on development of fruit defects and fruit loss in the chain.

1. Which actors are in involved in the chain?
2. Which product type(s)/varieties are handled in the chain?
3. How many customers do you supply with the product(s)?
4. How many quality levels of the product are handled in the chain? (e.g. highest grade only, 3 different grades – high, medium and low grades, etc)
5. Which are the main fruit handling stages in the chain? (harvesting, grading, packing, etc)
6. Which are the main critical control points in the chain? (harvesting, grading, etc)
7. What is the geographic distance between different actors (grower, packer, warehouse, retailer, etc) in the chain?

B. Assessment of Quality Control

A higher level of quality control is reflected by use of sophisticated methods for product control, use of sophisticated methods to monitor technological conditions and use of appropriate fruit handling procedures. Examples include use of procedural and systematic methods such as statistically valid sampling at every critical point.

1. What methods are used to assess fruit quality in the chain? (visual inspections, computer vision systems, etc)
2. Which fruit properties are measured in the chain?
3. At which stages or points in the chain are these inspections and or measurement of fruit properties done? (e.g. harvesting, receiving, packing, storage, etc)
4. How often are inspections and/or measuring of fruit properties carried out in the chain?
5. What equipment is used to monitor time-temperature and relative humidity conditions?

6. Which factors are considered in determining the time-temperature and relative humidity conditions to store and/or transport fruits? (e.g. fruit quality, set standards, etc)
7. How often are the monitoring instruments calibrated?
8. Which other conditions besides temperature and relative humidity are monitored in the in the chain?
9. Which points in the chain do you consider to be critical to development of fruit defects?
10. What criteria do you use to identify/establish critical control points in the chain? (e.g. use experience, historical data, predictive modelling, etc)
11. What quality control mechanisms are in place at these critical control points?
12. How accessible and understandable are the fruit handling procedures? (e.g. available to every employee, written in the language every employee understands, etc)
13. What other quality control measures are in place to reduce or prevent incidence of fruit defects in the chain?

C. Assessment of Logistics Control

The assumption is that a higher level of logistic control will result in a reduced incidence of fruit defects in the chain as the right fruit batch is picked at the right time before development of fruit defects. A higher level of logistics control is reflected by a use of highly flexible inventory issuing system, coordination of logistics activities and/or processes in the chain and appropriate handling of fruit in the chain (packaging and stacking arrangement of batches).

1. Which inventory issuing system(s) do you use? (e.g. FIFO, LIFO, FEFO, LQFO, HQFO, SRSL, etc)
2. Which factors are considered when deciding on the issuing policy? (e.g., period of time fruit has been in storage, fruit quality, propensity to develop defects, etc)
3. How is the logistics function organized in the chain? (E.g. centralized, individual actors organize own logistics, etc)
4. How are fruit handling stages/activities minimized in the chain? (e.g. standardization of crates, packaging, cross-docking, etc)
5. How do you stack batches at all handling stages (e.g. stacked on the floor, stacked on pallets, etc)
6. How do you ensure that batches are stacked within the refrigerated zone?
7. How do you ensure that cases of overfilled or under filled packs are minimised? (e.g. through final product inspection, etc)
8. What other logistics control measures are in place to reduce or prevent incidence of fruit defects in the chain?

D. Assessment of Quality Controlled Logistics

Quality controlled logistics is characterizeds by the integration of logistics control and quality control through use of time dependent quality information. A higher level of quality controlled logistics is reflected by use sophisticated methods to predict incidence of fruit defects, exchange of quality information flexibility of the delivery system to match specific consumer requirements.

1. How do you predict incidence of fruit defects in the chain? (using historical data, expert knowledge, quality decay models, predictive modeling, etc)
2. What type of information is exchanged in the chain? (e.g. fruit quality at a given time, chain conditions, etc)
3. The information is used for what purposes? (e.g. predictions, inventory control, etc)
4. How is the information exchanged? (e.g. EDI, internet, paper work, etc)
5. How frequent is this information exchanged?
6. How do you decide on time-temperature and relative humidity conditions to store and/or transport fruits in the chain? (e.g. standard for every batch, depends of fruit quality, etc)
7. On what basis are fruits segregated into homogenous batches in the chain? (e.g. variety, fruit quality/grade, remaining shelf life, ability to produce ethylene, etc)
8. How do you determine the duration a product is in storage? (e.g. fixed duration, depends on quality of produce, depends on demand, etc)

E. Assessment of performance indicators

Percentage incidence of fruit defects in the chain and the percentage of fruit thrown away as waste are the two indicators used in this study to measure the effectiveness of a given level of control (quality control, logistics control and quality controlled logistics) in minimising incidence of fruit defects and percentage fruit losses in the chain.

1. What are the major fruit defects that occur in the chain?
2. Which factors influence incidence of these fruit defects? (e.g. damage due to temperature/chain conditions, damage during fruit picking etc)
3. What percentage fruit defects per batch is due to mechanical damage and due to physiological defects?

    a. Mechanical damage (e.g. due to humans handling, machine parts)........................
    b. Physiological defects (e.g. due to temperature, moisture etc)................................
    c. Other causes: ....

4. What percentage of fruits is thrown away due to each of these fruit defects? (per batch, week, month)

ANNEX B: Data collected from cut Flower Growers - Kenya

Question	Grower A (Roseto)	Grower B (Xflora)	Grower C (P.J Dave)	Grower D (Desire Flower)	Grower E (Masai Flowers)
Area under production and daily productions	• 23 varieties are grown under on 18 hectares (18 greenhouses) • 75 to 140 stems are harvested daily from each greenhouse	• 10 varieties of 20 hectares • About 5 000 stems are harvested a day	• About 10 tonnes is harvested daily	• 5 varieties on 10 hectares • About 2-3 tonnes is harvested daily	• 20 hectares • About 10 tonnes is harvested daily
What is the distance from your premises to the airport?	• 180 km • 3-4 hour journey to airport	• 220kms • 4-5 hours journey to airport	• 40 km • 40 minutes journey to airport	• 50 km • 30-45 minutes journey to airport	• 45km • 30-45 minutes journey to airport
Percentage of flowers affected by defects on weekly basis	• Cumulative percentage damage is about 4-5%, and varies per season (e.g. *B. Cinerea* and powdery mildew more pronounced in summer)	• Cumulative percentage damage is about 4 - 6% and varies per season	• Cumulative percentage of defects is about 4-6% and varies per season	• Cumulative percentage of defects is about 4-6% and varies per season	• Cumulative percentage of defects is about 5-6% and varies per season
Causes of defects	• Temperature (low/high) • Pests and diseases • Improper human handling • Nutrition (over feeding and under nourishment)	• Temperature (low/high) • Pests and diseases • Improper human handling • Nutrition	• Temperature (low/high) • Pests and diseases • Improper human handling • Nutrition	• Temperature (low/high) • Pests and diseases • Improper human handling • Nutrition	• Temperature (low/high) • Pests and diseases • Improper human handling • Nutrition
Maximum accepted defects	Maximum of 5% per each type of damage, above which a Corrective Action Report (CAR) is written and the supervisor is summoned to explain why detected defects are high	Maximum of 5% per each type of damage, above which a CAR written and the supervisor is summoned to explain why detected defects are high	Maximum of 4% per each type of damage, above which a CAR written and the supervisor is summoned to explain why detected defects are high	Maximum allowable defects are 5% per each type of defects above which a CAR is written and supervisors summoned to explain the causes	Maximum allowable cumulative defects are 3% only above which a CAR is written and supervisors summoned to explain the causes
Method of harvesting	• Manual harvesting • Stems of different length/sizes are	• Manual harvesting • Stems are arranged according to size in	• Manual harvesting • Stems of different length/sizes are	• Manual harvesting • Stems of different length/sizes are	• Manual harvesting • Stems of different length/sizes are

	harvested together and carried on the harvester's arms before placed into buckets according to stem size	harvesting baskets before placed in buckets according to stem size	harvested together and carried on the harvester's arms before placed into buckets according to stem size	harvested together and carried on the harvester's arms before placed into buckets according to stem size	harvested together and carried on the harvester's arms before placed into buckets according to stem size
What is the lag time between moment of harvest and time flowers are received at the receiving bay?	20-30 minutes and also depends on proximity of greenhouse to the packing shed	30-40 minutes and also depends on proximity of greenhouse to the packing shed	30-40 minutes and also depends on proximity of greenhouse to the packing shed	30-30 minutes and also depends on proximity of greenhouse to the packing shed	30-40 minutes and also depends on proximity of greenhouse to the packing shed
Do you have facilities for pre-cooling or vacuum cooling	Harvested flowers are immediately put in a cold room for pre-cooling at 4 ^{o}C for 4 to 7 hours	Harvested flowers are immediately put in cold room for pre-cooling at 4^{o}C for 4 hours	Harvested flowers are immediately put in cold room for pre-cooling at 2^{o}C for 4-6 hours	Harvested flowers are immediately put in cold room for pre-cooling at 4 - 6^{o}C for 3-4 hours	Harvested flowers are immediately put in cold room for pre-cooling at 4 - 6^{o}C for 6 - 12 hours
What type of facilities is grading carried out in?	Temperature controlled room – water system used to cool the room.	Closed building with no conditioning. The room is big and grading tables are large allowing proper handling of stems	Closed building with no conditioning. The room is crowded and grading space limited as the tables are very small	Closed building with no conditioning but all doors into the grading room have air curtains that blow cold air to prevent warm air coming in.	Closed building with no conditioning. The room is big and grading tables are large allowing proper handling of stems
What type of facilities is packing process carried out in?	Flowers are packed in the cold room under 2-3^{o}C	Flowers are packed in the cold room under 2-3^{o}C	Flowers are packed in the cold room under 2-3^{o}C	• Flowers are packed in the cold room under 2-3^{o}C • Flowers are dried for 30 minutes before packing to avoid condensation of moisture as the micro-environment in the box is warmer	Flowers are packed in the cold room under 2-3^{o}C
Temperature in final cold room	Temperature (2-3^{o}C)	Temperature (2-3^{o}C)	• Temperature (2-3^{o}C)	Temperature (2-3^{o}C)	Temperature (2-3^{o}C)
What type of vehicle is used to transport the flowers to	Unrefrigerated and sealed trucks are used Trucks depart around 03.30am to avoid warm weather during the day	Refrigerated trucks are used but when production is high, hired unrefrigerated trucks are also used. Trucks are	Unrefrigerated but sealed trucks are used Trucks depart around 03.30am avoid warm weather during the day	Refrigerated trucks are used. Trucks cooled until temperature inside is 2 ^{o}C before flowers are loaded. The loading bay has	Refrigerated trucks are used but when production is high cooled until temperature inside is 2 ^{o}C before flowers are loaded.

airport?		cooled until temperature inside is 2 ^{o}C before flowers are loaded.		inflated sides preventing warm air to enter the truck during loading	
Duration flowers exposed to ambient temperature during the grading process	The grading process of a bucket of flowers (20-40 stems) takes about 30-40 minutes and flowers are out of storage during this time	The grading process of a bucket of flowers (20-40 stems) takes about 30-40 minutes and flowers are out of storage during this time	Flowers exposed to ambient temperatures for 30 – 40 minutes during the grading process	Grading process takes about 20 minutes for a bucket. Flowers are removed from storage in small quantities reducing time they are exposed	Flowers exposed to ambient temperatures for 30 – 40 minutes during the grading process
What product parameters are measure in the chain	Cut flowers are inspected for damage, uniformity in stem length, bud size, temperature	Cut flowers are inspected for damage, uniformity in stem length, bud size, temperature	Cut flowers are inspected for damage, uniformity in stem length, bud size, temperature	Cut flowers are inspected for damage, uniformity in stem length, bud size, temperature	Cut flowers are inspected for damage, uniformity in stem length, bud size, temperature
At which points in the chain is quality of the flowers inspected?	1. Receiving bay 2. When removed from pre-cooling for grading 3. About 12 quality checkers are present during the grading process 4. Graded flowers are inspected before final storage 5. Inspected during packing	1. Receiving bay 2. When removed from pre-cooling 3. 4 quality checkers are present during the grading process 4. Graded flowers are inspected before final	1. Receiving bay 2. During grading of flowers – 3 quality inspectors are present in the room 3. Graded bunches are certified by an inspector 4. Bunches are inspected after packing	1. Receiving bay 2. When flowers are removed from pre-cooling 3. 6 quality checkers are present during the grading process 4. Graded flowers are inspected before final storage 5. Inspected during packing	1. Receiving bay 2. When flowers are removed from pre-cooling 3. About 3 quality checkers are present during the grading process 4. Graded flowers are inspected before final storage
Which points in the chain do you consider to be critical to development of flower defects?	• Handling during harvesting • All points at which flowers are out of storage • Final inspection is critical, should be able to detect any defects	• Handling during harvesting • All points at which flowers are out of storage • Final inspection is critical, should be able to detect any defects	• Handling during harvesting • Grading is important and all defects should be eliminated • Final inspection is critical, should be able to detect any defects	• Handling during harvesting • All points at which flowers are out of storage • Final inspection is critical, should be able to detect any defects	• Handling during harvesting • All points at which flowers are out of storage • Final inspection is critical, should be able to detect any defects
What criteria is used to identify critical control points	• CCPs not defined • No systematic method is used for identifying CCP	• CCPs not defined • No systematic method is used for identifying CCP	• CCPs not defined • No systematic method is used for identifying CCP	• CCPs not defined • No systematic method is used for identifying CCP	• CCPs not defined • No systematic method is used for identifying CCP

Are employees trained on any aspects of maintaining a cold supply chain?	• Training is offered daily using corrective action reports (CAR) from previous day's quality checks. • All handlers are made aware of their mistakes and corrective action taken	• Training is at least once a week using corrective action reports (CAR) of that week • All handlers are made aware of their mistakes and corrective action taken	• Training is offered daily using corrective action reports (CAR) from previous day's inspections carried out. • All handlers are made aware of their mistakes and corrective action taken	• Training is conducted every week and frequency depends of percentage of defects noted that week • All handlers are made aware of their mistakes and corrective action taken	Employees are trained every Tuesday during inspections/visits by management.
Monitoring of chain conditions temperature and humidity	• Temperature and humidity in the cold rooms are recorded manually every hour. • Temperature of flowers when they are loaded into trucks is recorded	• Verdict data loggers are used for monitoring temperature throughout all stages in the chain • Humidity is not measured	• Only temperature is monitored in the chain • Temperature of the flowers is recorded when at the following stages • Temperature of flowers when they are loaded into trucks is recorded	• Only temperature is monitor through visual inspections of the temperature displays. • Temperature of flowers when they are loaded into trucks is recorded	• Verdict data loggers are used for monitor temperature throughout the chain • Humidity is not measured
Appropriateness of procedures manuals	Procedure manuals are available at all handling stages and during grading, the procedure manuals and standards are available at every working station	Procedure manuals are available at all handling stage in the chain, though not at every working station in the grading room	Manuals and procedures are not displayed at all stages in the chain. Where they are displayed, they are few and incomplete.	Manual are at every working station from the greenhouse up to loading point	Procedure manuals are available at handling stage in the chain, though not at every work station in the grading room
Arrival temperature at the airport	The arrival temperature at the airport varies between 4 - 7 ^{o}C	The arrival temperature at the airport varies between 4 - 7 ^{o}C	The arrival temperature at the airport varies between 4- 6 ^{o}C	The arrival temperature at the airport varies between 3 - 6 ^{o}C	The arrival temperature at the airport varies between 3-5 ^{o}C

Please Note: All the information in the above table is given by managers or supervisors of the farms. Participatory observation was very limited and very few data was extracted from record. This was due to time restrictions.

ANNEX E: Quality Controlled Logistics Model (Van der Vosrt et al. 2007)