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The Influence of Cool Chain Management on the Shelf Life and Quality of Horticultural Products: Review

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Abstract
The ever rising of population growth around the world necessitates the food demand greatly. The available land produces constant quantity of product per given area despite to the liner increment of food demand. Conversely, some of the produced food may not be reached to the end consumer due to food inaccessibility, food loss and food wastage which may still able to feed million of peoples who are living under nourishment. The horticultural crops are a perishable product due to its highest moisture content which deteriorate by high temperature. However, this temperature effect can be managed to its lowest optimum storable of individual products by cold chain management system at all levels of movements. The Cold chain logistics management is a systematic logistics project which the temperature sensitive products are always provided in low temperature environment in every aspect of production, storage, transportation, marketing and consumption to ensure quality of goods. Cold chain constitutes four aspects of frozen processing, frozen storage, refrigerated transport and distribution and frozen sales. The proper cold chain management system reduces a significant quantity loses of horticultural fresh products which occurred between harvesting and consumption period. At storage house and during transporting, the temperature adjustment according to the crop optimum lower temperature is a crucial activity of cool chain management. At the final, temperature management of produce at retailer shop is a component of cool chain management system to supply quality product to end consumer. The temperature management activities can be regulated by conventional thermometer, electronic data logger, and smart wireless autonomous micro system and time temperature indicator to control the temperature breakage that occurred in cool chain management system at any point and time that makes cool chain management as efficient to pro long the shelf life of the products.
Keywords: Food Waste; food loss; Temperature; Storage; Transportation;whole seller; Retailer; Deterioration

1. Introduction

The demand of food crops around the globe has been increasing at an alarming rate in order to feed the ever opening mouth due to the high rate of population growth. However, according to FAO (2009), the agriculture in the 21st century faces multiple challenges to produce sufficient food and fiber to feed the rapidly growing population that expected to grow by 2.3 billion people at the end of 2050 which highly observed in developing countries especially the sub Saharan Africans that would share the growth by 114 percent. Meeting the needs of these additional people will require substantial increases in production of agricultural systems using essentially the same area of arable land as is used today, or less due to expansion of cities (Yadav, 2015). But, production of the required amount of food product would have been hindered by shortage of cultivated lands, land degradation due to deforestation and over grazing, non predictable climate changes like prolonged drought, devastating flooding, biotic and abiotic factors will contribute a lion share to a shortage of food production globally in general and in developing countries in particular (Alexandratos and Bruinsma, 2012). The food shortage will happen when the world is consuming more than it is producing, leading to increasing in food price (Tilman *et al.,* 2011). This food shortage creates the suffering of nutrient deficiencies 'hidden hunger', which leads to a social and political instabilities.

However, according to the estimation of FAO, almost a third by weight (1.3 billion tones) or a quarter in terms of calorific content, of all food produced globally is lost or wasted every year (Winkworth-Smith, 2014). The loss is occurred in developing countries due to mishandling of the product starting from harvest at farm level to the final consumer table, whereas in the developed countries it is due to consumer's food wastage (Kummu *et al.,* 2012, Gustavsson *et al.*, 2011). These loss and waste accounts 25% to 50% which can feed a millions of peoples who are under nourished if it is handled properly (Kitinoja, 2013). A Proper Post harvest handling is crucial in order to save this huge losses and wastes by using different post harvest technologies at appropriate time and places until it reaches to the final consumer table. The use of cold handling and storage of perishable foods is important method to decrease these losses and wastages by starting at farming field to consumption that creates enough food availability to reduce its shortage (Rahemi, 2006). In order to keep a food product shelf life before it has been arrived to the consumer table, the knowledge and understanding of the particular crop characteristics and the management systems are paramount important to enhance the food availability throughout of the year. Nii Ayi Quaye (2011) pointed out that the cold storage facilities can keep the freshness and quality of the food products without deterioration for the required period of time. So that, it is

possible to reduce the food loss and food wastage by continuous management of the cooling storage without any short break until it reaches to the end consumers (Winkworth-Smith *et al.,* 2014). Therefore, the aim of this review paper is to discuss the Influence of Cool Chain Management on the Shelf Life and Quality of Horticultural Produces after harvest to the final consumers table.

2. The nature of horticultural crop products

In most horticultural crops like vegetables and fruits a nutritional quality contents (vitamins, minerals, organic acid compounds) and other product components are available at their fresh states because the most constituents of the crop is water (Rahemi, 2006). Since it is a living entity and due to its high water contents, horticultural crops can easily subject to desiccation (wilting, shriveling) and mechanical injury especially after harvest (El-Ramady, 2015). It mean by that due to the high moisture content and tender nature of the crop, they can easily perishable as compared to the other cereal crops if not carefully handled after they removed from their mother plants. According to El-Ramady (2015) suggestion, an estimated 20–30 % of fresh horticultural produce is lost after harvest due to miss handling of the crop and these losses can assume considerable economic and social importance. Environmental factors like temperature have an inevitable contribution for horticultural crop deterioration after their harvest. Brosnan (2001) elaborated its effects as most of the highly perishable horticultural products including leafy and flowering vegetables are easily deteriorated unless they are immediately pre cooled as soon as possible after they are harvest and before bringing in to cold storage. This is due to the rise of temperature that triggers the metabolic processes of the products including of the respiration rates, the production of ethylene gas and increases the amounts of water loss through transpiration from the product that would have a direct proportion for product spoilage (Álvares, 2007). Finally, the product leads to devastation by micro organisms which can easily create deterioration that brings to the final product loss. Therefore, keeping the temperature fluctuation after harvest until it arrives to the end consumers by using of the appropriate horticultural post harvest technology like cool chain managements is the paramount important activity to prolong the shelf life of fresh horticultural. Before the products have gone to store or transport to the targeted areas, they should be pre cooled to remove the field heat to its safest optimum storable temperatures.

2.1 Pre Cooling of fresh horticultural products

Temperature is one of the most limiting environmental factors which affect the post harvest shelf life of fresh horticultural crop (Brosnan and Sun, 2001). It affects the Quality of the product after harvest by accelerating their metabolic activities like physiological and biological chemical processes of the produce that leads to spoilage. While the produces are attached to their mother plants, they supplied to required foods and water by photosynthesis and transpiration mechanisms (Kitinoja and Kader, 2002). But after harvest, it is impossible to substitute these lost substances rather than leaving to dying. However, it is paramount important reducing of the deleterious effects of temperature by removing the field heat of the crop to the storable temperature which is called 'precooling' of the product until it will have arrived to the end consumers. Brosnan and Sun (2001) defined precooling as the method of removing the field heat from freshly harvested produce in order to slow down the metabolic process and creating unfavorable environment for micro organisms growth as well as to reduce the water loses from the surface of the produce by transpiration. Baird and Gaffney (1976) also added that the pre cooling is likely the most important method of all the operations used in the maintenance of desirable, fresh and salable of horticultural produce. Therefore the precooling is the method of lowering the produce temperature in order to reduce the deterioration that will happen by above safe level of optimum temperature which came from the field heat. According to Gowda *et al.,* (1997) finding report, prior to pre cooling of foods like fruits and vegetables that usually more than 90% of water may be subjected to a pre wetting process before pre cooling in air due to the assumption of the presence of moisture loss from the surface of the produce by heat in the air when it is not saturated. Also another similar finding was reported by Álvares *et al.,* (2007) on the parsley leave pre cooling by using of hydro cooling method. They found that, the hydro cooling method of precooling was reduced the loss of fresh weight of the product from the leaves of parsley in the first twelve hours of storage and maintained the relative water content (RWC) at a high level even after seven days of storage at 5^{o}C. The finding clearly stated that, the hydro cooling method has been used for both immersion and shower beside to pre cooling purpose which is very important to remove the field heat from the product before storing the parsley leaves. Rennie *et al.,* (2001) also added on the effects of different vacuum pressure for lettuce precooling. They pointed out that the different pressure levels of vacuum haven't significant effects on storage life of lettuces and prolonged its shelf life's. These because of Vacuum cooling is a rapid evaporative cooling technique which is an advantageous than the other methods including shorter processing times, consequent energy savings, improved the product shelf life, quality and safety of the products (McDonald and Sun, 2000). Moreover, all these findings are indicating that the horticultural produce should be pre cooled after they detached from their mother plants to reduce the effects of field heat like respiration, minimization of water loss from the product and retarding the development of decay caused by pathogens in order to pro long the storage life of the

products. Different types of pre cooling methods like room cooling, forced air cooling and crashed ice cooling are available to pre cool the products after they harvest from their parent plants and prior to taken to storage room and transported to the targeted areas of end consumers.

2.2 Cool chain managements of horticultural products

The fresh horticultural produce is living entity after they harvested and they continue the process of internal respiration which produces CO2, water and heat (Kader and Rolle, 2004). The heat produced from these products results in the warming of the products which leads to the deterioration before it will arrive to the end consumers. The rate of respiration is highly temperature dependent even if the individual products have its own different respiration rates (Fonseca *et al*., 2002). They further illustrated that the Produce which is kept cool will have a low respiration rate with limited heat production and low rate of deterioration. Therefore, horticultural crops must be cooled in refrigeration at their lowest save temperature from harvesting to the final consumer by managing the temperature fluctuation at each point of cold chain management systems (Kitinoja and Kader, 2002). The Cold Chain managements are the management system of a produce temperature from the point of harvest to the final consumer table in order to maintain the quality of the products (Beasley, 2002). Yan and Lee (2009) also illustrated as Cold-chain management is a systematic logistics project which the temperature sensitive products are always provided in low-temperature environment in every aspect such as production, storage, transportation, marketing and consumption to ensure the quality of goods. It also considered as a low-temperature logistics process which based on refrigeration technology. Cold chain constitutes four aspects of frozen processing, frozen storage, refrigerated transport and distribution and frozen sales. This proper cold chain management system saves a significant quantity loses of horticultural fresh products from deterioration at any points.

2.2.1 Cool chain managements of horticultural product in the storage

Temperature management is the most effective tool for extending the storage life of fresh horticultural commodities because of the postharvest life of a fruit extended by cooling is that metabolism is slowed by low temperatures (Lurie, 2002). The best storage environment for an individual fruit and vegetables are depends on its unique requirements for temperature, relative humidity, and ethylene exposure. Each 10°C decrease in temperature will reduce respiratory activity by a factor of 2 to 4 rates (Mitchell, 1992). Lurie, (2002) also pointed out that lowering of the temperature suppresses the rate of ethylene production. He was clearly elaborated that further the ethylene synthesizing enzymes, 1 -aminocyclopropane carboxylic acid (ACC) oxidase and ACC synthase are sensitive to low temperatures and as the temperature has lowered, less ethylene will be produced. The lower temperature also affects the rate of growth and spread of pathogens which lower directly their metabolic activities and a certain fungi that can cause severe losses to the harvested product do not grow at low temperatures. So that, the fresh products should be stored at safe optimum of low temperature near to 0 ^{o}c in order to reduce the high temperature effects as shown in the table 1 below. The importance of cold chain will be only realized if the cold storage is managed properly with regards to temperature, relative humidity levels, air circulation, adequate space between storage bins, trays and containers, the mixing of compatible produce, as well as the management of product in and outflows which should follow the ‘First In, First Out’ principles (FAO, 2009).

Table 1 Storage temperature and duration of fruits

Fruit	Storage temperature (C)	Duration (weeks)
Grape	0	4-12
Grape Fruit	10-13	4-8
Guava	8-12	2
Kiwifruit	0	16-20
Lemon	12-14	-16
Loquat	0-2	3
Lyche	0-2	4
Mandarin	5-8	2-6
Nectarin	0	2-4
Orange	4-6	4-8
Orange	4-6	4-8
Papaya	12-14	2
Peach	0	2-4
Pear	0	16-20
Permison	0-1	12-16
Plum	0	3-6
Pomegranate	0-1	12-16
Pummel	8-10	8-12
Tangerine	5-8	8-12

Source; Michael Kneel, (2002)

2.2.2 Cool chain managements of horticultural products during transport

The globalization of fresh produce trade is creating a need for better long distance transportation systems and handling methods to preserve produce quality. During long distance transport of horticultural crops, a temperature control is the vital issue by enabling air circulation to carry away the heat produced by the product, mostly heat from air infiltration and heat conducted across the walls of the vehicle coming from the environment (Kitinoja and Kader, 2002). They added that traveling during night and at early morning can reduce the heat produced in the vehicle during horticultural crop transportation. The product of horticulture crops move from one corner of the world to the other parts by different transporting systems by keeping of the optimum temperature of the track. According to Vigneault *et al.,* (2009) report, approximately 40% of the vegetables deteriorated at supermarket shelves are due to damage during transit. The refrigeration system used in a transport vehicle must have adequate cooling capacity and the temperature control is crucially important and it should be kept at optimum safe conditions during transport. Therefore, it is important to consider extreme high or low temperature conditions when calculating the cooling capacity of the produce in the vehicle (Vigneault *et al.,* 2009). At destination, pallet covers and wraps are being removed and temperature and quality of the produce will be inspected. Above all, an adequate temperature control systems, relative humidity control, CO_2 concentration control, ethylene control and air circulation systems are the most important means to ensure quality preservation of perishable horticultural products (Kitinoja and Kader, 2002).

2.2.3 Cool chain managements of horticultural products in retailer's shop

When the product arrives at its destination, maintaining of the lowest feasible temperature of the product is important (Kitinoja and Kader, 2002). According to Vigneault *et al., (*2009) suggestion, the Produce arrived at market destination within 2°C of its optimum temperature range should be immediately transferred to a refrigerated room and Produce more than 2ºC above its recommended temperature range needs to be rapidly cooled again. Therefore, Temperatures of the display tables or refrigerated supermarket displays should be suited to the commodity on sale. Since if display cabinets or counters do not have the refrigeration capacity to cool produce, fruits and vegetables should be at their optimum temperature before being stacked for display. To prevent an increase in temperature during display, produce should not be stacked above the load line of the display cabinet or counter (Kitinoja, 2013). Consumers should also keep their product at minimum temperature until they will bring to the spoon of the end consumers.

2.2.4 Temperature monitoring system on cool chain management of horticultural products

Temperature monitoring and control are essential mechanisms in Cold Chain Management systems, because they are necessary for maintaining food safety and quality until it reaches to the end consumers (Kuo and Chen, 2010). The Product temperature is the most important factor affecting the quality of horticultural produce by producing the heat beside to the environmentally supplied heat. Therefore, during cool chain managements system, a temperature regulation is the most important activity in order to reduce the deterioration of horticultural products. These could be done by conventional thermometer, electronic data logger, and smart wireless autonomous micro system and time temperature indicator (Navam, 2015). Even if it is difficult to maintain temperature break at some point, these temperature monitoring systems are the most crucial to regulate the ever fluctuating of the

temperature to prolong the shelf life of the product.

Summary and conclusion

a significant amount of the produced calories has been wasted and lost both in developed and developing countries respectively which able to feed a million of peoples who is living undernourished around the world. These loses and wastage are happened due to improper handling of the farm product especially the horticulture commodities which is easily deteriorated at each channels of movements from production area to the end consumer spoon due to different factors like temperature. However, these loses and wastes can be minimized by applying different proper handling techniques like cool chain managements which control the deleterious effects of temperature at the storage, transport, processing and retailer shops. A cool chain management is an important technique of temperature management systems which control the temperature fluctuations to the optimum lower temperature at any point after harvesting by monitoring systems like conventional thermometer, electronic data logger, smart wireless autonomous micro system and time temperature indicator. These activities can minimize the food losses and wastes which can increases the food availability at the required time and places by reducing the consequence of food unavailability around the world. Generally, the cool management system of horticultural crops after they detached from their mother plants are crucial at any channels of movement from the point of production area to the last consumers to reduce the deterioration has been occurred by temperature flactuation.

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