REDUCTION OF POSTHARVEST LOSS OF AVOCADO THROUGH IMPROVED POSTHARVEST HANDLING PRACTICES.

By

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DECLERATION

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A report on this has not been submitted to any other University for another degree.

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Dedicated

To

My loving

Amma, Thaththa, Akka, and Nangi

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ABSTRACT

Postharvest loss of avocado is reported to be around 40%. Major causes for the loss are disease development, poor ripening and poor external appearance. Of the problems stem end rot and development is the serious problem for the high loss.

The Experiments were done to study the effect of removal of stem end on postharvest behavior of avocado (*Persea americana Mil).* Two avocado varieties were used. Avocado fruits were harvested at fully mature stage with stalk attached to the fruit. Then stalks were removed from half of the fruits while the stems were remained in other half. This was tested for both type of avocados.

Avocado fruits were placed in ventilated plastic bins and VQR, % of Postharvest weight loss, Disease Severity index, % of postharvest loss due to the diseases was obtained of each fruit for 10 days at room temperature (27°C – 29°C).

It was observed that postharvest loss of 40% can be reduced down to 20 - 26% by keeping stalk attached to the fruits.

Another experiment was carried out to check the Stage of maturity at harvest on Stem end rot and Anthracnose incidence of avocado. This was done using fruits of one variety harvested at 3 different stages; fully mature, maximum fruit size and Just before reaching maximum size.

According to the result showed that the lowest postharvest loss due to the diseases occurrence was observed in fruits harvested at in maximum fruit size which was only 26.6%. Where as other two stages showed a disease incidence of 33.33%.

The study also showed that the attached or detached of stalk did not had a significant effect on Anthracnose but had a significant affect on Stem end rot; with a higher disease incidence when stalk was detached. It was further shown that disease incidence also depend on the storage period and the variety of avocado.

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CHAPTER 1

INTRODUCTION

Avocado (*Persea americana Mill*) (*Persea gratissima Gaerth)* belongs to the family lauraceae and climacteric class of fruits (Nethsinghe, 1993). They are mostly evergreen trees and shrubs, occasionally aromatic and native mostly to tropical and subtropical regions. The collections of fossil avocados were made in several widely spread areas of California as well as in other parts of America (Hulume, 1971). USA is the largest commercial producer with a total yield of about 60,000 tons per year. The horticulturist between three general ecological groups or races of the avocado: Mexican, Guatemalan and West Indian. Mexican avocado is considered to be the best in the World.

The Sri Lankan avocados were described as *Persea gratissima;* of which is a cross pollination of West Indian and Guatemalan (Parson, 1933). The extent of the avocado cultivation in Sri Lanka is about 770 hectares and the approximate annual of Kandy, Kegall, Badulla, Nuwera-Eliya, Matale, etc. Avocado the most nutritious fruit found in Sri Lanka. As a valuable food source, this fruit has exceptionally high minerals (Fe, mg, k) vitamins (A, C, E and essential B vitamin) and protein contents. It is a very good source of highly digestible oil containing unsaturated fatty acid (Hulume, 1971).

Sri Lankan markets are mainly for fresh consumption of sweet buttery flesh of mature fruits. During the main avocado season i.e. mid May to early August and the minor bearing season i.e. from late December to early January, price is their lowest while during the off season, a several folds increase could be observed. During the year 1995, 11,000MT of avocado have been produced and exported 373kg. These exports have earned Rs 22,000. Avocado fruit has some potential as an export crop for Sri Lanka present and in future. The marketing situation is such that in certain regions an excess supply leads to low price and wastage.

The postharvest loss of avocados has been estimated as 40% (Council for Agricultural research Policy, 1998). These include weight loss, loss of food value, loss of economic value, loss of quality or acceptability and actual loss of commodity. Main factors that cause the postharvest losses are mechanical damages through careless handling and harvesting, pest and diseases and physiological disorders. As well as transport, inadequate storage, immature harvesting cause to shrivelling, infection of diseases, rough handling and adverse

temperature (Sarananda, 2000). The World production and postharvest losses of avocado in less developed countries are 2036,00 tones and 43% respectively (Paull, 1991). Avocado is high demanded fruit. They are harvested when horticultural mature but in an unripe state (Nethsinghe, 1993). Growers and traders who lead to high postharvest loss do not often follow maturity indices.

Fruit contain a high amount of moisture and are rich in nutrients. Thus they are vulnerable to microbial attack and easily degradable by either chemical or physical means which leads to their perishable nature. Anthracnose (*Collectotrichum gioesporioids*) and stem end rot (*Phoma spp, Botryodiplodia theobromae* and *Phomopsis spp*) are recognized as major postharvest diseases in avocado fruit (Adikaram, 1998). Among the fungi identified in rotting fruits in Sri Lanka stem end rot is a postharvest disease that causes occasional severe loss in avocado fruits (Ploctz et al., 1997). Fruit with broken stem ends are particularly like develop stem end rot. The disease is common in stored fruit (Lindycoates *et al.*, 1995).

Reduction of postharvest loss can reduce the unit cost of production, lower the retail price and increase the farmer's income. Preventing loss is cheaper than producing more of the same quantity and quality. In addition improving handling practices is less risky than improving the yield by addition of inputs.

The mature avocado fruits are harvested by cutting or snapping off the stem at the base of the fruit with about 12mm of the stem attached (Nakasone and Paull, 1998). Completely removal of stem ends in the method practical by traders in Sri Lanka before sending fruit to market. Removals of stem end causes a mechanical damage to the fruit which facilitate the microbial infection specially stem end rot (sarananda, 2000). This leads to very high postharvest loss of avocado at the market. Therefore keeping the stem end attached to the fruit is very important.

Avocado is a high demanded fruit. It should not be harvested until they have reached the degree of maturity at which they will ripen to an acceptable eating quality. They are harvested when horticultural mature but in an unripe state (Nethsinghe, 1993). Mature avocados do not ripen on the tree, but soften several days after being picked (Hizrach *et al.*, 1999). So it is commercially important to identify the maximum maturity (i.e. the maturity index).

Harvesting fruit with stalk attached can prevent mechanical injuries. In addition stage of maturity at harvest may also have an effect on the disease incidence because immature fruit take longer time for ripening. So it is commercially important to identify the maximum maturity and to adopt improved postharvest technologies to minimize the postharvest losses.

Objectives;

1. Effect of removal of stem end on postharvest behaviour of avocado.

2. Stage of maturity at harvest on Stem end rot and Anthracnose incidence of Avocado.

CHAPTER 2

LITERATURE REVIEW

2.1 Origin and Distribution

Avocado is a 'new world' origin fruit. There is a general agreement that the centre of origin of the *Persea*, including the avocado is in the high lands of central and east central Mexico and in the adjacent high lands areas of Guatemala (Nakasone and Paull, 1998). Early European travellers during the sixteen-century found avocado on cultivation and distributed throughout Central America and northern South America and widely spread to the all around the world. The date of introduction to Sri Lanka in May 1927. Nowadays it is widely distributed in the Kandy, Bandarawella, Nuwaraeliya and Baddula Districts etc.

2.1.2 Agronomy

The avocado does not favourable to grow in the dry zone: and it is essentially a fruit for the wet zone, where it grows best in the mid country at heights 1000 to 3500 feats on well drained soils (Nethsinghe, 1993). The ideal soil for avocado is a loam of medium texture overlying a porous sub soil. Heavy clay soils, which get water logged during rains, are not suitable. Avocado is said to grow in tropical and subtropical reagents were the rain fall ranges from 75cm to 580cm during monsoon ((Nethsinghe, 1993).

2.2 Botany of Avocado

Avocado (*Persea americana Mill*) (*Persea gratissima Gaerth*) belongs to the family lauraceae. The laureal family (lauraceae) is compost of about 47 genera with 2000 – 2500 species. They are mostly evergreen trees and shrubs, ocationally aromatic and native mostly to tropical and subtropical reagents (Nakasone and Paull, 1998).

Botanical Classification and Other Names of Avocado

Order	:	Ranaleas.
Family	:	Lauraceae.
Genus	:	Persea.
Species	:	(*Persea americana Mill*) (*Persea gratissima Gaerth*)

Other Names.

Sinhala	:	*Aligatapera.*
Tamil	:	*Anakoya Pallam.*
English	:	Avocado.
French	:	Avocotier
Portuguese	:	Abacate.

2.2.1 Pollination and Fruit Set

Avocado flowers are born in clusters at the tip of the branches. The inflorescence appear by the thousand, each carrying hundreds of flowers. These flowers are smooth and greenish in colour. It flowers open twice and is closed in between the first time it functions as a female. The second time as a male (Bergh, 1969). So verities are classifies in to A and B types according to the manner in which the flower parts functions.

Table 2.1 Flowering pattern of type A and Type B Pattern avocados.

Type of flowers	Day 1		Day2	
	Morning	Afternoon	Morning	Afternoon
Type "A" Flowers	Female	Closed	Closed	Male
Type "B" Flowers	Closed	Female	Male	Closed

(Piccone and Whiley, 1986).

2.2.2 Fruit

The avocado is a one seeded berry. The single large seed is compost of two cotyledons enclosing and embryo is surrounded by a thick fleshy mesorcarp (Nakasone and Paull, 1998). The skin varies in thickness to 0.65cm, depending upon the race and has 20,000 – 30,000 stomata per fruit, less than on a leaf, the skin colour of the ripe fruits range from varies shapes of green to yellow green and from reddish to maroon and light to dark purple. The buttery flesh (mesocarp) is greenish yellow to bright yellow to Craemish when ripe. Oil content range from 7.8 to 40.7% on a fresh weight basis (Kawano *et al.*, 1976). Size varies from small fruit of some Mexican types, about 227g or less to the large Guatamalan types 1.4 to 2 Kg or more.

In shape the fruit is usually pyriform to oval and round. In West Indian and Mexican cultivars, the fruit mature 150 to 240 days after anthesis while Guatemalan cultivars take more than 250 days (Nakasone and paull, 1998).

Avocado fruit are large and pear shaped and weight from 85g to about 1000g. Each fruit contains a single large seed, which amounts of about 8 -25% of the weight of the fruit and is reported to contain 1 – 2% oil. The pulp has a buttery texture, a rich nutty flavour and greenish yellow colour. The green skin gets a yellow tint (purple in some varieties) on ripening (Nethsinghe, 1993).

2.3 Recommended Verities

Three ecological races (subspecies) are recognised; Mexican (subtropical), Guatemalan (semitropical) and West Indian (tropical), Mexican avocado considered to be the best in the Wold (Nethsinghe 1993). According to the parsons, the Sri Lanka three are a variation of *Avocado gratissim;* (syn, *Avocado Americana*) embracing the West Indian and Guatemalan types .Present commercial varieties are products of natural hybrids of these three races. The important avocado cultivars in Sri Lanka are Pollock, Gottfried, Peradeniya purple, Fuerte, Simmond, Tower ii, Booth 7, etc (Department of agriculture, 1996).

2.4 Maturity and Quality

Fruit maturity at harvest has a great effect on the eating quality and keeping quality. Unfortunately, a fruit harvested at the time when it has optimum eating quality often does not have the best keeping quality. Fruit harvested earlier often has better keeping quality but poor eating quality.horticultural or commercial maturity is generally defined as the development stage when harvested fruit can undergo normal ripening and achieve acceptable eating quality and appearance (Lee *et al.*,1983).The distance to the market, the handling, storage and transportation methods and facilities available, are largely determined by the stage of maturity at which a fruit is harvested. The basic data of the relationship between harvest maturity, eating quality and keeping quality should be collected in order to develop useful maturity standards. Horticultural maturity of avocado fruit can be defined as the growth stage at which harvested fruit will undergo normal ripening (Mizrach *et al.,* 1999). A major problem is the stage of maturity for harvest especially for cultivars that remain green upon ripening. Most countries with commercial avocado production have developed some sort of standards for determining maturity (Paull and Nakasone, 1998).

2.4.1 Determining Maturity

It is commercially important to identify the minimum maturity (i.e. the maturity index) that ensure acceptable quality when ripe, but allow early harvesting to obtain the higher early season prices (Hofman and Jobin, 1999)

Investigations to identify maturity indices for avocado have been conducted for about 60 years (Lee, 1981). These maturity indices are generally developed by correlating a potential indicator with fruit quality when ripe. Avocado fruit have a number of characteristics that indicate harvest maturity. These characteristics include;

- Fruit stalk is longer, swollen and distinctly yellow, rather than green;
- Seed coat is dry, dark and somewhat shrivelled, rather than pale whitish;
- Fruit is generally larger but not always so;

Skin is dull and lustreless, with a powdery appearance, rather than shiny (the usefulness of this characteristic is variety dependent, for example, it is not much use on the early, thin skinned types such as Bacon); (Department of agriculture western Australia, 2000).

In Sri Lanka slight change in rind colour and size are taken as the indication of maturity for harvesting. In other countries different criteria like specific gravity oil content, dry matter content, and moisture to oil proportion method are used. Avocado oil content increases during fruit development. It was one of the early maturity indices (Lee *et al.*, 1983) and it is still the most reliable indicator (Kaiser, 1994). However, cost and difficulty of measurement resulted in investigations for (% DM) is strongly related to oil content and quality (Lee *et al.*, 1983; Degan et al., 1986; Ranney, 1991).

When define the Maturity State one or more characters also the following can be used;

- Fruit are large in size
- Skins of the matured fruits are less shine
- Lenticels are shown distinguishes
- Sound of the seed in the fruit (Only for some varieties)
- Seed coat becomes dark brown
- Flesh is cream colour

(Sarananda, 2000).

2.5 Harvesting of the Avocado Fruit

Avocado belongs to the "Climacteric class" of fruits. But the fruit does not ripen on the tree (Louris, 1991). They are harvested when horticulturally mature, but in an un ripe state .If mature will soften after harvest. The harvesting season in Sri Lanka is July to October (Nethsinghe 1993). When harvesting, early morning harvesting is favourable (Sarananda 2000). In harvesting two major aspects are emphasized, maturity indices and harvesting methods studies of maturity indices are aimed at establishing the stage of fruit development for optimum harvesting since this is closely associated with the storage life and eating quality of the fruits.

Branches of avocado tree have brittle nature. Therefore climbing tree is not a usable method. The ladders, picking bags, picking poles are used when plucking the fruits. Mature fruits are harvested by cutting or snapping at the base of the fruit with about 12mm of stem attached (Nethsinghe, 1993). Due to the marketing condition in Sri Lanka avocados harvesting in do at once and do not practice suitable harvesting practices or improved handling practices. So this leads to higher amount of postharvest loss of avocado (Sarananda, 2000).

2.5.1 Standards

According to the international standards, avocados should have a 1 – 2 cm long and the place where the stalk is cut should be clean. The fruit shall be free from any attack by fungi and insects, from open wound and from effects of excessive exposure to sunlight (Nethsinghe, 1993).

2.6 Postharvest Behaviour of Avocado

The potential post harvest life of fruit is determined, not only by the genetics of the fruit, but also by may preharvest factors, weather, plant nutrition and cultural practices (including chemical sprays) affect post harvest diseases as well as physiological disorders. Avocado fruit does not ripen on the tree but, if mature will soften gradually after harvesting and fruit ripen within 8 to 10 days without shrivelling. When an immature fruit is harvested, it will not ripen properly and take longer to soften and they shrivel upon storage with the flesh becoming rubbery rather than buttery (Nakasone and Paull, 1998). When over ripe one will decay rapidly after harvest (Mizrach *et al.*, 1999).

Fruits harvested before they reach full maturity on the tree will probably softening but they will often shrivel and lack acceptable eating quality (Stanley, 1998). Fruit may late few days to several weeks to softening after removing from the tree. This time depend on the avocado variety, stage of maturity and temperature (Nethsinghe, 1993). The fruit of the most cultivars hangs well on the tree after reaching maturity. When harvesting fruit should be with a part of the stem attached. The stem is said to contain a ripening inhibitor, thus allowing the fruit to keep for a longer period.

Postharvest physiology deal with the time period from harvested or removal of fruit from its normal growing environment to the time of ultimate utilisation, deterioration or death. When preharvest and harvesting factors have a direct influence on postharvest responses (Stanley, 1998). The horticulture and food research institute 1998, it is clear that pre harvest exposure of fruits to the sun can result in a wide range of postharvest responses (Asllam *et al.*, 1999).

2.6.1 Ripening

Avocado being a climacteric class of fruit is expected to liberate ethylene at the ripening in high concentration (Adel and kadel, 1992). But avocado ripens only after the harvesting. Other phytohomones also appear to be important in the ripening response. Many avocado cultivars do not ripen while attached to the tree, suggesting that some inhibitor produced by the parent plant is operative. When fruits are detached from the tree the rate of ethylene synthesis increase (Stanley, 1998).

The fruit does not ripen on the tree. Because the stem is said to contain a ripening inhibitor. But the exact nature of the ripening inhibitor is not known. However it contains to exert it's effects for about 24 hrs. When harvesting the fruit which detached from the branch with the peduncle (stalk) attached, ripen later than when it removes (Stanlay, 1998). Mature avocado fruits ripen with in a week at 27c0(Saman, 1980). In low temperature ripening process cause retardation. If fruits are picked too early (immature) they will not ripen properly.

During postharvest period climacteric fruits undergo significant changes in their pigment composition (colour) (Stanley, 1998). When avocado ripening specially for some cultivars that remain green upon to ripening. Some green colour avocado develops a yellow wish tint on the stem near the fruit. Maturity of cultivars that normally change skin colour from green to radish or purplish likes the "Hass"(Nakasone and Paull, 1998).

2.7 Postharvest Loss of Avocado.

Posthaverst losses reduce either the quality or quantity or both. Quantitative losses of fruits are readily apparent and qualitative losses are frequently overlooked or under estimated are of importance because they can considerably reduce a crop's value.when we speak of losses of food crops, we refer to many deferent kinds of loss, produced by a variety of factors. These include weight loss, loss of food value, loss of economic, loss of quality or acceptability and actual loss of commodity. Less evident consequences of postharvest deterioration include reduced shelf life of the product, possible contamination with a mycotoxin, softening of processed fruits etc. (Aslam, 1980). Most horticultural products, which are highly perishable. The situation unfortunately has tended to de-emphasise the importance given to postharvest period of organic crops even through extensive losses do occur (Stanley, 1998)

Posthaverst deterioration causes severe losses of both time and money. Posthaverst deterioration is a serious problem, not only for the producer or distributor of fresh fruits but also for the consumer by adversely influencing the availability and cost of this commodity (Coursey and Booth, 1972). While good quality fruit at harvest is a first requirement,proper Posthaverst handling procedures such as packaging cooling refrigerated transport and container are just as essential if this quality is to be maintained.Ministry of agriculture Sri Lanka reported that the estimated Posthaverst losses in fruit production is around 40% with concerning the total fruit production for year 1998.

Table 2.2 Percentage of postharvest loss of avocado

Crop	Producer	Collector	Wholesaler	Retailer	Total
Avocado	04	08	16	12	40%

Source; (Ministry of Agriculture and Land, 1998).

2.7.1 Factors Affecting Postharvest Losses

2.7.1.1 Physical Factors

In general there are four critical factors that effect the rate of postharvest losses of fruits. These are the nature of the fruit, its moisture content, and the temperature and oxygen concentration of the storage environment. Therefore proper handling and storage can greatly extend the functional utility of these products (Stanley, 1998).

Losses caused by mechanical injury are frequently overlooked. However these enhance physiological and pathological losses. Mechanical injury occurs in many forms and from preharversting through harvesting and all handling operations (careless handling practices/rough handling). When harvesting do not consider about maturity, immature harvesting cause to happen shrivelling also infection of diseases.

After harvesting completely removal of stalk cause to occur mechanical injuries to the fruit. Do not used suitable condition, containers and handling practices in transport and do not practice favourable conditions in storage also cause to severe postharvest losses (Sarananda, 2000).

2.7.1.2 Physiological Factors

2.7.1.2.1. Transpiration

The fruit losses water by transpiration. But no solid mater is lost like in the case of respiration. The loss of moisture from fruit occurs through the stomata, lenticels and other openings associated with the epidermal cells. The weight loss due to the transpiration is many times bigger than loss of weight resulting from respiration. Excessive transpiration during postharvest storage of avocado may causes uneven ripening. While attached to the plant, the loss of water due to the transpiration is compensated by water absorption by roots. But after harvesting no water supply and only the water loss continues. The total weight of fruit is continuously decreasing during storage (Stanley, 1998).

2.7.1.2.2 Respiration

The avocado is a climacteric fruit and its ripening associated with an increase in respiration, referred to as climacteric rise (Biale, 1954). The dry matter lost in the case of respiration, so the total weight of the fruit decreases.

2.7.1.3 Maturity of the Crop at Harvest (refer 2.4)

2.7.1.4 Pathological Factors

Anthracnose and stem end rot is recognised as major postharvest disease in avocado fruit. Young fruits are usually free from visible symptoms and characteristic decay lesions both diseases develop during fruit ripening (Coates *et al.*, 1995).

2.7.1.4.1 Diseases

Anthracnose

Causal orgenism: *Collectorichum gloesporiodes* (Penz).

The Anthracnose disease originates from quiescent infections in the immature fruit long before harvest (Binyamimni and schiffaman –Nadel, 1972). The diseases cause a fruit drop and rot and reduce the fruit shelf life during storage and transport. It is most important postharvest disease in the world, causing losses on fresh fruit. Anthracnose contributes to about 80% of total disease in avocado (Johnson *et al.*, 1997).

The initial infection takes place when the fruits are on the tree during any part of its growth from flowering to mature and remains quiescent usually. The further development of the disease is manifested during storage transport and marketing (Snowdon, 1990). Anthracnose is a latent infections, that are appear as fruit soften symptoms of these latent infections are similar to the larger fruit spots seen at harvest (Coates *et al.*, 1995).

Stem end rot

Cause a range of fungi including *Dothiorella aromatica, Losiodiplodia theobromae syn, Botryodiplodia theobromae, Thyronectria pseudotrichia and Phomopsis perseae.*

Stem end rot is a postharvest disease that causes occasional severe losses in avocado fruit. (Ploetz *et al.*, 1994). When detached the stem end scar is an ideal point of entry for wound pathogens and causes severe rotting. Therefore, after harvesting if suitable preventive

measures were implemented it taken will lead to severe rotting which account for higher percentage of postharvest losses (Snowdon, 1990).

The stem end of the fruit darkens and begins to soften while the rest of the fruit remains firm. The stem falls out revealing a grey – coloured button. If fruit are placed in warm humid conditions, greyish fungal mat will appear over the neck of fruit. When infected fruit are cut in half, a dark brown rot is seen to extend down into the body of the fruit. Brown streaks also appear, running longitudinally down around the seed. The internal quality of fruit deteriorates rapidly once fruit begin to soften (Coates *et al.*, 1995).

2.7.1.5 Pest

Many insects pest attack avocados but they seldom limit fruit production significant. Insect infections are not predictable and control measures are justified only when large population builds up. The fruit fly attack damage may reduce the market value of the fruit. The infestation can be controlled by fruit fly trap – using pheromones. Fumigation with methyl bromide and subsequent cold storage are standard procedures for disinfecting avocados infested with fruit flies (Nethsinghe, 1991).

2.7.2 Reduction of Postharvest Loss of Avocado

Increasing the availability of food has become an ever more pressing problem, with the world population expanding at a faster rate than that of food production. So world hunger is widespread and growing. According to the World Bank estimates about sixty percent (60%) of the people is poor and less developed countries do not meet their caloric and protein needs. Then there is a great need to increase food supplies, especially protective foods such as fruits and vegetables which are valuable sources of essential nutrients, mineral, vitamins and fibre.

Avocado the most nutritious fruit found in the world. Reduction of postharvest loss is more cheaper than producing more of the same quantity and quality and also prevent losses of both time and money. However, the development and application of improved handling method and facilities can often reduce losses in quality and quantity. The extent of these losses can be reduced through better understanding of the nature of harvested product and use of appropriate technology (Stanley, 1998).

Postharvest treatment is necessary and the most effective way of reducing losses and maintaining quality is to educate the growers to harvest and handle their fruit carefully. Improving handling practices is less risky than improving the yield by addition of the inputs. Avocado pear like fruits are susceptible to different kinds of damage is a major cause of quality losses, it is necessary to know the strength properties of the fruit. Such properties help in devising proper equipment for harvesting, storing, transporting, processing and general handling of avocados (Baryeh, 2000).

2.7.2.1 Method of Preventing Postharvest Loss of Avocado

Consideration in harvesting, minimising mechanical injuries and harvesting fruits, stalk attached to the fruit (Sarananda, 2000).

1. At harvest it is important to identify the minimum maturity that ensures acceptable quality when ripe (Hofman and Jobin, 1999).
2. Careful handling transport and rapid cooling are recommended.
3. Optimum temperature storage (10°C – 12°C).
4. Wrapping in polythene bags.
5. Wax coating and cellophane wrapping.
6. Calcium salts and latex treatments.
7. Controlled and modified atmospheric storage.
8. Application of fungicides.
9. In order to reduce the loss of avocado, it is necessary to know the strength properties of the fruit. Such properties help in devising proper equipment for harvesting, storing, transporting, processing and general handling of avocados (Baryeh, 2000).

2.7.2.1.1 Consideration in Harvesting, Minimising Mechanical Injuries and Harvesting Fruits Stalk Attached to the Fruit

When detached the stem end scar is and ideal point of entry for wound pathogen and causes higher percentage of postharvest losses (Snowdon, 1990).

To prevent the postharvest loss, mature fruits are harvested by cutting or snapping off the stem at the base of the fruit with about 12mm of the stem attached (Paull and Nakasone, 1998).

Infected fruits harvested with short stalk (2 – 3 mm), stem end rotting before ripening is completed; in contrast fruits harvested with longer stalks (6 – 10 mm) are able to ripen before decay processes into the fruit (Snowdon, 1990).

Postharvest loss of avocado can be reduced to some extent by harvested fruit with stalk attached to the fruit (Sarananda, 2000).

According to the international standard, avocados should have a stalk 1 – 2 cm long and the place where the stalk is cut should be clean (Nethsinghe, 1993).

2.7.2.1.2 At Harvesting it is Important to Identify the Minimum Maturity that Ensures Acceptable Quality when Ripe

In Sri Lanka slight changes in rind colour and size are taken as the indications of maturity for harvesting. In other countries, different criteria like specific gravity, oil content, moisture to oil proportion methods are used. A higher yield can also be obtained if harvesting staggered, with 50% of fruit harvested with 21% dry matter and the remainder at 30% (Paull and Nakason, 1998). When dry matter percentage is greater than 21%, the fruit is considered to be mature; this can increase to 30% dry matter in more mature fruit. After moisture content has been determined, fruit comparable to the sample fruit can be picked and ripened at room temperature. If the sample fruit ripen within 8 – 10 days without shrivelling, they are considered to be mature and the grower can proceed to harvest comparable sized fruit on the tree (Nakason and Paull, 1998). Horticultural or Commercial maturity is generally defined as the development stage when harvested fruit can undergo normal ripening and achieve acceptable eating quality and appearance (Lee *et al.*, 1983). The postharvest loss of avocado could be reduced if the growers aware of the above treatments for storage and precautions to be taken during the harvest.

2.8 Important of Avocado

The avocado is a fruit of high nutritive value. No other fruit is rich in fat, protein, minerals and vitamin A and B. the fat content vary from 2 to 30% of the fresh fruit according to the variety but the quality of the monounsaturated oleic acid, followed by palmetic and linoleic acids (Burgh, 1992). Avocado oil commands a high price and is used in superior quality soaps, salad, oils and pharmaceuticals.

Avocado, its high calorific values, and very low carbohydrate content, the avocado makes an admirable food for diabetic patients. Presently they are consumed as fresh fruits. The fruit increases the diet's content of antioxidants, foliates, K and fibre (Rainey *et al.*, 1994). Most of the fat available in avocado is monounsaturated believed by scientists to protect against heart diseases.Avocado is a popular fruit crop among Sri Lanka. It has some what stable market all over the country in the season. As well as Sri Lanka has a considerable export potential for avocados. It is mainly used fresh in fruit. By processing technology processed products from under-utilised fruits, such as frozen desserts, various types of salads, cocktails, frozen bread spread, etc. (Gunasena, 1999).

2.8.1 Nutrition

Avocado fruit is a valuable food source, this fruit has exceptionally high mineral (Fe, Mg, K) vitamins (A, C, E and essential B vitamin) and protein contents. It is a very good source of highly digestible oil containing unsaturated fatty acids (Hulume, 1971). The protein content of 1 –2 % is considered to be greater than in any other fruit (Burgh, 1992). Avocados has "calorific value three times that of banana and one and one – half times that of beef steak with abundant amount of vitamins A, B and E and mineral matter higher than other fruit"(Wardlaw, 1937). The fruit also increases the diet's content of antioxidants, foliates, and fibre (Rainey et al., 1994). Avocados are nutrient dense in potassium, dietary fibre, vitamin C, E, thiamine, riboflavin, nicotinic acid, pyridoxine, folic acid and pantothenic acid and are a healthy substitute for butter (Atukorale, 2001).

Avocados are a cholesterol free, sodium free low saturated food with only 5.0 g of fat per serving a level acceptable for inclusion in a low fat diet (Atukorala, 2001).

Table 2.8.1.1 Nutrient content in 100g fresh weight of the edible parts of the avocado

Component	Amount (g)
Water	59 –86
Crude protein	0.8 – 4.4
Digestible carbohydrate	1.2 – 10
Crude fat	5.0 – 32
Crude fibre	1.50
Calcium	10.00
Phosphorous	27.00
Iron	1.00
Vitamin A.I.U	2.00
Thiamine	0.07
Riboflavin	0.15
Niacin	1.00
Vitamin C	10.00

Energy content in 100g fresh weight of edible part is 210 – 920 kJ.

Source: (The cultivated plants of tropic and subtropics 1997).

2.8.2 In Medication

Robert Atkins creator of Diet nutritional program stated in recent issue of his Health Revelations News letter that avocados help guard against post prandial (after eating) increase in blood sugar which is good news for people with insulin resistant of type ii diabetes. It is no wonder that he refers to avocado as having" no equal in nature "; however many people believed that due to high oil content eating avocado increases the total serum cholesterol. But now it has been understood that it has no cholesterol (Encyclopaedia of nutrition, 1993). A medical research institute in Germany has estimated that about 60 – 70% of avocado fat is monounsaturated and 65% of this is oleic which is said to be anti – artery clogging and with cholesterol lowering abilities.

Avocado is said to be and excellent remedy in acute digestive disorders due to its blandness and high vitamin content and superior to mouth lotions and other remedies for bad breath. Avocado oil has many applications in medicine such as an effective treatment for many skin diseases psoriasis, dermatitis, etc. as a dressing for skin burns, as a base for post operative and surgical dressing, as a protective agent against rickets etc. It has a high oil soluble vitamin content also a high penetration capacity into the skin and has skin healing properties. The fruit skin contains antibiotics.

Avocado can also protect one against heart diseases " phytochemicals found in avocado may help fight heart disease and cancer" says Jeanette O Toole of Caliconia avocado. The phytochemicals such as betasitsterol and the antioxidants such as glutathione found in avocado prevent chronic illnesses such as cancer according to Dr. David Herber, Director of UCLA centre for Human nutrition.

Australian Scientists have reported that people consuming anything from half to one and a half avocado a day can lower their cholesterol more than people eating a low fat diet. The high content of mono – unsaturated fat in avocado is thought to be responsible for the hypocholesterol aemic property. Avocado has the highest content of mono – unsaturated fat which brings down cholesterol as compared to all other fruits available in Sri Lanka (Atukorale, 2001).

In conclusion, avocados are a cholesterol free, sodium free low carbohydrate. That promotes health, wellbeing, and fitness of diabetic patients and also can protect one against hard diseases.

2.8.3 Processing

Most fruits are seasonal. During one period of the year they come into the markets abundantly causing a surplus which ultimately leads to high postharvest losses. In another season it is very hard to find even a single fruit.

Avocados in Sri Lanka are mainly grown for fresh consumption of sweet buttery flesh of mature fruits. It is hard to find the processed avocado products yet in Sri Lankan markets. But in foreign good markets we can se a large number of productions. Now days in this country also there are some attempts to find the potentials for avocado processing (Fernando, 1996).

Avocado mainly used fresh in salads, its high fat content combining well with acid fruits and vegetables, such as pineapple, citrus, tomatoes or with acid dressings. A major commercial processing of avocado product is "Guacamole", used as favourite dip with potato chips and similar products. Avocado may be used to supply the fat content of frozen desserts, such as ice – creams and sherbets (Miller *et al.*, 1965). By processing technology different value added to products such as jams, jellies, marmalades, ready to serve drinks, cordials, squashes and carbonated drinks etc. developed from the fruits.

CHAPTER 3

MATERIALS AND METHODS

3.1 Experiments

The experiments were carried out in the microbiology laboratory, Food Research Unit, Department of Agriculture, Gannoruwa, Peradeniya.

3.1.1 Preliminary Studies

Fruits were bought from Peradeniya town in Kandy district and they were transported to the laboratory within 15 minutes. Then they were categorized as stalks attached and stalk detached fruits. Then the weights were recorded from an electronic balance (Mettler P 1210). Fruits were numbered and divided in to two sets as stalks attached and stalk detached. Then the two sets were placed in ventilated aluminium trays. All the fruits were allowed to ripen at room temperature. The following observations were made for quality comparison.

3.1.1.1 Observations

Observations were recorded each day of the week for 10 days.
The observation were

1. Percentage of weight loss.
2. Visual quality rating of fruits.
3. Disease index / severity.
4. Percentage of post harvest loss due to diseases.

3.1.1.1.1 Percentage of weight loss (moisture loss)

Weight of each replicate was measured daily using a laboratory balance (Mettler P 1210) and weight loss was determined on individual fruits from each group. With the measurement of the initial weight and final weight of fruit, the difference between weight loss was expressed with respect t storage time.

Percentage of weight loss was calculated by using the following formular

$$\% \text{ of weight loss} = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} * 100$$

3.1.1.1.2 Indexes Used in this Study

All replicates were checked using following indexes during period of experiment (storage).

3.1.1.1.2.1 VQR (Visual Quality Rating Index)

1. None, edible, for most discoloration and shrivelling (Limit of edible).
2. Slight edible, up to 30% of surface affected.
3. Moderately edible up to 20% of surface affected limit of edible.
4. Severe more than 10% of surface affected.
5. Fair, defects moderate defect.
6. Little, more fair, slight defects.
7. Good slight defects. .
8. Better, slight defects.
9. Excellent (Maria and Quintana , 1993).

3.1.1.1.2.2 Disease Severity Index

0 - No disease

1 - 10% disease

2 - 11 - 20% disease

3 - 21 – 30% disease

4 - More than 30% (Maria and Quintana,1993)

3.1.1.1.4 Percentage of Post Harvest Loss Due to Diseases

The number of diseased fruits out of total fruits was calculated as a percentage after the storage period.

$$\% \text{ of post harvest loss due to the disease} = \frac{\text{Rotten fruit}}{\text{No of fruits used for experiment}} * 100$$

3.1.2 Experiment I: Effect of Removal of Stem End on Postharvest Behaviour of Avocado

Fully mature avocado fruits were harvested from two varieties of avocados grown at home garden in Nuwara - Eliya District. All the fruits were harvested with long fruit stalk attached to the fruits by manually. Fruits were the placed in ventilated plastic crates as a single layer and care fully transported to the laboratory with 5 hr. One half of the fruits of each variety the stem was detached completely as trading practice. The other half of each variety the stem was trimmed leaving about 0.5-cm fruit stalks attached to the fruit.

All the fruits were numbered (as 1-15) and the weights of individual fruits were recorded from an electronic balance. Numbered groups of fruits were placed in four bins separately (1-4). One of bins consisted of 15 fruits and lids were closed partially for partial ventilation.

Percentage of weight loss, Visual Quality Rating of fruits, Disease severity index, % of postharvest loss due to the diseases were recorded daily in fruits was stored at room temperature and the duration was 10 days.

- Statistical analysis: 2*2 factorial in completely randomized design.

3.1.3 Experiment II: Stage of Maturity at Harvest on Stem end rot and Anthracnose Incidence of Avocado

Avocado of 3 different stages of maturity, fully mature, just obtained maximum fruit size (maximum size) and just before reaching maximum fruit size were harvested from a single tree at Mandaramnuwara in Nuwara – Eliya district. All the fruits were harvested with the fruit stalk attached by manually.

Fruits were placed in ventilated plastic crates and carefully transported to the laboratory. Fruit stalk of all the fruit was trimmed leaving about 0.5-cm fruit stalk attached to the fruit. Each fruit was then numbered and weighted using an electronic balance (Mettler p 1210). Fruits of each maturity stage were transferred into separate 15 and plastic bins and the lids were closed partially for partial ventilation.

Percentage of weight loss, VQR, Disease severity index and percentage of postharvest loss due to disease were recorded periodically.

- Statistical analysis: in completely randomized design

CHAPTER 4

RESULTS AND DISCUSSION

A significantly higher weight loss in variety II was observed during the storage compared to that in variety I (Table 4.1.1). However no significant difference in weight loss was observed between detached and attached stem in both varieties. Table 4.1.2 shows removal of stem end had no effect on weight loss of avocados stored for 10 days.

Weight loss of a harvested fruit is mainly due to moisture loss through transpiration and dry matter loss through respiration (Stanley, 1998). Weight reduction in both varieties of avocado tested in the experiment confirms both moisture loss and dry matter loss has taken place. However, variety II had a higher weight loss compared to that in variety I. Although fruits used for the experiment were mature the fruits of variety II were smaller compared to variety I. Since the shape of both varieties was similar the reason for higher weight loss in variety II may be due to higher surface area/volume ratio. When fruit are large, less surface area / volume ratio result less moisture loss. Dry matter loss of both varieties would have been more or less similar because all fruits were harvested at fully mature stage. There may be varietals difference in respiration, which was not recorded in this study. Normally mechanical wounds caused by detaching of the stems results high moisture loss, it was not significant in this study.

Table 4.1.1. Mean % of weight loss of avocado stored at room temperature (27°C - 29°C) for 10 days.

Treatment	% of weight loss
Stalk attached fruit (variety I)	10.2127 B
Stalk detached fruit(variety I)	10.6216 B
Stalk attached fruit (variety II)	12.0596 A
Stalk detached fruit(variety II)	11.9631 A

Means followed by the same letter in the column are not significantly different by LSD (P>0.05). Each data point represents the mean of at least 15 data values.

Table 4.1.2 Mean % of weight loss of avocado for stalk attached and detached fruits.

Treatment combination	% of weight loss
Stalk attached fruit	11.3406 A
Stalk detached fruit	11.0879 A

Means followed by the same letter in the column are not significantly different by LSD (P>0.05). Each data point represents the mean of at least 30 data values.

A significantly higher visual quality in variety I stalk attached fruit was observed during the storage period (10 days) at room temperature (27°C – 29°C). There was no significant different between stalk attached fruit of variety I and variety II stalk detached fruits. However stalk attached fruits of variety I significantly different from stalk detached fruits of variety II (Table 4.2.1). The removal of stem end had an effect on visual quality of fruits. Table 4.2.2 shows that there was a significant different among stalk attached fruits. The highest VQR was observed in stalk attached fruits.

A significant reduction in VQR was observed in all fruits during storage up to 10 days at storage. A least VQR was observed in avocados stored for 10 days at room temperature.

Avocado is a climacteric fruit (Stanley, 1998). Primary loss in quality is due to the induction of fruit and changes in flavour, colour and texture. VQR in both varieties of avocados shown in the experiment confirms stalk attached fruits was better than detached. However, avocado which stalk attached to the fruit gave good quality with lesser disease incidence (Specially stem end rot).

Avocado fruit which detached from the branch with the stalk attached, ripen later than when it removed (Stanley, 1998). However it was not significant in this experiment.

Mature avocado fruits ripen within a week at 27°C (Saman, 1980). It was observed in this study also. During postharvest period avocados under go significant changes in their colour. Variety I changed green to yellowish green colour and variety II was changed green to purple. Purple colour variety showed better appearance due to less prominent disease symptoms on the skin. When maturity fruit ripening normally change their skin colour from green to yellowish green to reddish or purplish (Nakasone and Paull, 1998).

Disease occurrence was associated with later storage of ripening, which causes reduction of quality at room temperature. Disease severity was increased day by day and it caused reduction of quality of fruits. Although fruits used for the experiment were confirmed good quality, reduction of quality was associated with later part of the storage.

Table 4.2.1 Mean visual quality rating of avocado stored at room temperature (27°C-29°C) for10 days.

Treatment	Visual quality rating
Stalk attached fruit (variety I)	7.2111 A
Stalk detached fruit(variety I)	6.8111 AB
Stalk attached fruit (variety II)	6.9222 AB
Stalk detached fruit(variety II)	6.6222 B

Means followed by the same letter in the column are not significantly different LSD (P>0.05). Each data point represents the mean of at least 15 data values.

Table 4.2.2 Mean visual quality rating for stalk attached and detached fruits

Treatment combination	VQR
Stalk attached fruit	7.0667 A
Stalk detached fruit	6.7167 B

Means followed by the same letter in the column are not significantly different LSD (P>0.05). Each data point represents the mean of at least 30 data values.

Table 4.2.3. Mean visual quality rating during the storage period.

Day	VQR
2nd	8.5750 A
6h	7.4917 B
10th	4.6083 C

Means followed by the same letter in the column are not significantly different LSD (P>0.05). Each data point represents the mean of at least 60 data values.

A significantly higher disease severity (Stem end rot) in variety II stalk detached fruit was observed (Table 4.3.1). There was no significant difference among variety II and I. However, a significant difference was observed among stalk attached fruits and stalk detached fruits of variety I. However no difference in disease severity was observed in variety II.

Table 4.3.2 shows that higher disease severity in stalk detached fruits. However removal of stem end had no significant effect on disease severity of avocados during storage period. But under visual examination there was a different. A significantly higher disease severity was observed in 10^{th} days (Table 4.3.3). However no significant difference in disease severity was observed in 2^{nd} and 6^{th} days.

Stem end rot is the main postharvest disease observed in avocados grown in Sri Lanka (Sarananda, 2000). Higher incidence of stem end rot observed in this study in agreement with the above statement. Symptoms of disease were started at the stem end. Early on set of the disease was always associated with stalk detached fruits. When severity of disease is higher, it was spread internally. It causes discoloration and softening of the fruits. Externally this rot appeared as a brown discoloration of the rind and spread all over the fruit at later stages of infection. However, the symptoms do not usually appear until the fruit ripening. Because the stem end rot is a latent infection (Coates *et al.*, 1995).

When detached the stem end scar is an ideal point of entry for wound pathogen and causes severe rotting (Snowdon, 1991). However the fruit that is harvested with stalk is less susceptible for the stem end pathogens. Harvesting fruits with stalk attached and trimming the stalk before sending to the market makes an entry to the pathogen from the stem region.

In addition this study confirms stem end rot could be reduced when stalk attached to the fruit until the fruit is ripening. Disease severity was increased at later part of the storage. This may be due to senescence of the fruits. However, when the stem end rot developed in the stalk attached fruit was only at over ripen stage. This clearly shows simply leaving the stem end attached to the fruit prevent the stem end rot development until they are consumed.

Table 4.3.1 Mean disease severity index (stem end rot) at room temperature (27°C-29°C) for 10 days.

Treatment	Disease severity index
Stalk attached fruit (variety I)	0.0889 B
Stalk detached fruit(variety I)	0.4444 A
Stalk attached fruit (variety II)	0.1556 AB
Stalk detached fruit(variety II)	0.2222 AB

Means followed by the same letter in the column are not significantly different by LSD (P>0.05). Each data point represents the mean of at least 45 data values.

Disease index;

0- No disease

1- 10% disease

2- 11 - 20% disease

3- 21 – 30% disease

4- More than 30%

Table 4.3.2 Mean disease severity index for stalk attached and detached fruits.

Treatment combination	Disease severity index
Stalk attached fruit	0.1222 A
Stalk detached fruit	0.3333 A

Means followed by the same letter in the column are not significantly different by LSD (P>0.05). Each data point represents the mean of at least 90 data values.

Disease index;

0- No disease

1- 10% disease

2- 11 - 20% disease

3- 21 – 30% disease

4- More than 30%

Table 4.3.3 Mean disease severity index during the storage period.

Day	Disease severity index
2nd	0.0000 B
6th	0.0000 B
10th	0.6833 A

Means followed by the same letter in the column are not significantly different by LSD (P>0.05). Each data point represents the mean of at least 60 data values.

Disease index;

0- No disease

1- 10% disease

2- 11 - 20% disease

3- 21 – 30% disease

4- More than 30%

Table 4.4.1 shows a significantly higher Anthracnose occurrence in stalk detached fruits of variety I. There was no significant difference among stalk attached two varieties. Significantly higher disease incidence was observed in stalk detached fruits variety I.

Removal of stem end had no effect on occurrence of Anthracnose (Table 4.4.2). However severity of disease was increased in later part of the storage. The highest disease occurrence was observed at 10^{th} day (Table 4.4.3).

Anthracnose is the next most important disease during ripening. It is a latent infection, that is present in the skin at harvest but not visible, but appears as fruit softenes (Coates *et al.*, 1995). It was observed in this experiment also. Two types of lesions occur on harvested fruits: numerous small black spots 10mm or more in diameter with circular diffuse margins (Coates *et al.*, 1995). Both types were observed in this study.

This disease causes reduction of fruit shelf life during storage. When disease severity was high pink, slimy spore masses erupt through the fruit surface and lesions may expand into the pulp of the fruit down to the seed. The area of decay remain fairly firm and only during later stages did lesions become completely soft. One to several spots of this type could cover the entire fruit. Postharvest decay due to Anthracnose was high when length of fruit storage increased.

Quality reductions in most fruits were observed at 10^{th} day. This study confirmed that the severity of Anthracnose causes postharvest loss of avocado. In addition it causes reduction of the quality of fruit other than quantity. There was an activity of fungi, which was not tested in this study.

Table 4.4.1 Mean disease severity index (Anthracnose) at room temperature (27°C-29°C) for10 days.

Treatment	Disease severity index
Stalk attached fruit (variety I)	0.5333 AB
Stalk detached fruit(variety I)	0.7778 A
Stalk attached fruit (variety II)	0.4667 AB
Stalk detached fruit(variety II)	0. 2000 B

Means followed by the same letter in the column are not significantly different by LSD (P>0.05). Each data point represents the mean of at least 45 data values.

Disease index;

0- No disease

1- 10% disease

2- 11 - 20% disease

3- 21 – 30% disease

4- More than 30%

Table 4.4.2 Mean disease severity index for stalk attached and detached fruits.

Treatment combination	Disease severity index Storage period 10 days
Stalk attached fruit	0.5000 A
Stalk detached fruit	0.4889 A

Means followed by the same letter in the row are not significantly different (P>0.05). Each data point represents the mean of at least 90 data values.

Disease index;

0- No disease

1- 10% disease

2- 11 - 20% disease

3- 21 – 30% disease

4- More than 30%

Table 4.4.3 Mean disease severity index during the storage period.

Day	Disease severity index
2nd	0.0000 A
6th	0.1167B
10th	1.3667 B

Means followed by the same letter in the column are not significantly different by LSD (P>0.05). Each data point represents the mean of at least 60 data values.

Disease index;

0- No disease

1- 10% disease

2- 11 - 20% disease

3- 21 – 30% disease

4- More than 30%

When the disease index level 3 was considered those fruits cannot be consumed hence considered as loss. Table 4.4.4 shows that removal of stem end causes higher level of disease development, resulting in very high postharvest loss. It was observed in both varieties. Although stem end rot is a latent infected disease the incidence can completely be managed if the fruit is kept free from wounds. In addition this study confirmes that the severity of Anthracnose also causes postharvest loss of avocado. It reduces the quality of fruit other than the quantity.

Table 4.4.4 Percentage of postharvest loss of avocado due to the diseases.

Treatment	% of postharvest loss
Stalk attached fruit (variety I)	20%
Stalk detached fruit(variety I)	40%
Stalk attached fruit (variety II)	26.66%
Stalk detached fruit(variety II)	33.33%

A significantly higher weight loss in fully mature fruits was observed during the storage at room temperature (27°C – 29°C) compared to those in other maturities (Table 4.5.1). However no significant difference in weight loss was observed between maximum and just before reaching maximum fruit size in the variety.

In the fruits attached to the plant, the water due to transpiration is compensated by water absorption by roots. But after harvesting water supply is not there and only the water loss continuous. So the total weight of fruit continuously decreased in storage (Stanlay, 1998) (Refer expt1 weight loss). Weight losses of all 3 stages of avocados were recorded in this experiment. It confirms that the total weights of fruits were continuously decreased in the storage.

The loss of moisture from fruits can be from stomata, lenticels and other openings associated with epidermal cells (Stanlay, 1998). When fruits are in fully mature stages, lenticels distinguish (Sarananda, 2000). However this experiment records that the moisture loss of fruits were higher in fully mature fruits.

Fruits harvested before reaching full maturity on the tree will often tend to shrivel. Excess moisture losses can cause due to diseases also (Nakasone and Paull, 1998). However it was not recorded in the experiment.

Table 4.5.1 Mean percentage of weight loss of avocado stored at room temperature (27°C – 29°C) for 7 days

Stage of maturity	% of weight loss of avocado
fully Mature	9.3733 A
Maximum fruit size	7.6140 B
Just before reaching maximum fruit size	8.1720 B

Means followed by the same letter in the column are not significantly different by LSD (P>0.05). Each data point represents at least 15 data values.

Table 4.6.1 shows that significantly highest quality of fruit was in the stage of maximum fruit size. Significant differences in visual quality rating (VQR) among different stages of maturity can also be seen. Fully matured avocados had the lowest quality.

A significant reduction in VQR was observed in all fruits during storage up to 7 days. A least VQR was observed in avocados stored for 7days at room temperature (Table4.6.2).

Avocado is a climacteric fruit (Stanley, 1998). During ripening fruit become soft. Therefore it is susceptible to microbial attack and quality or quantity or both deteriorate with senescence. It was tested in this study and confirmed.

Mature avocados ripe within a week at 27°C (Saman, 1980). In this study it was observed that the fully matured avocados were ripening within 3 – 4 days and after that over ripening taken place.
When fully mature avocados were kept for longer periods in storage at room temperature, it caused over ripening of the fruit and more susceptible to diseases. Then fruits decay rapidly.

The avocado fruits of maximum size were ripened within 5 – 6 days; but the fruits harvested before reaching maximum fruits size were ripened at last. When immature fruits are harvested it will not ripen properly and take longer time to soften and are more susceptible to microbial infections. It causes reduction of quality of fruits (Nakasone and Paull, 1998). This study records that, the quality of the fruit just before reaching maximum fruit size is lower than the quality of maximum fruit size.

This study confirms that the maximum size of fruits had good keeping quality and eating quality. Fully mature fruits had good eating quality but with low keeping quality. When harvesting is considered, the maximum fruit size stage is the best.

Table 4.6.1 Mean visual quality rating of avocado stored at room temperature (27°C-29°C) for 7 days.

Stage of maturity	Visual quality rating
Fully Mature	6.6667 C
Maximum fruit size	7.5333 A
Just before reaching maximum fruit size	7.1333 B

Means followed by the same letter in the column are not significantly different by LSD (P>0.05). Each data point represents the mean of at least 45 data values.

Table 4.6.2 Mean Visual quality rating during the storage period.

Day	VQR
1st	8.8667 A
4th	8.1111 B
7th	4.3556 C

Means followed by the same letter in the column are not significantly different by LSD (P>0.05). Each data point represents the mean of at least 45 data values.

It was observed that the higher disease severity in fully mature and just before reaching maximum fruit size (Table 4.7.1). It was observed that lowest disease severity in maximum size. However, no significant differences in disease severity were observed among all 3 stages.

However severity of diseases was increased in the latter part of the storage. The highest disease occurrence was observed at 7th day (Table 4.7.2). This may be due to senescence of the fruits.

In this experiment it was observed that the presence of Anthracnose is the major problem in all maturity stages. However less matured fruits (just before reaching maximum fruit size) and over ripen (fully mature fruits change to over ripe) fruits had relatively high disease occurrence. Stem end rot was not common in this experimental period of storage. This may be due to that all fruits were attached with stalks or there may be varietals difference also.

Fully mature avocados turned into over ripen at 7 days. The just before reaching maximum fruit size of avocados take longer period to turn to ripen stage. Most diseases occur at the ripen stage. After harvesting if it takes long time to ripen, fruits may be more susceptible to diseases like Anthracnose. Normally avocado fruits are not ripen by artificial methods. Over ripening can cause rapid decay (Mizrach *et al.*, 2000).

Disease severity in 3 stages of avocado tested in this study confirms both just before reaching maximum and fully mature fruits (over ripened) had higher severity. However, the disease development continued to increase through out the storage.

Table 4.7.1 Mean disease severity index of avocado stored at room temperature (27°C – 29°C) for 7 days.

Stage of maturity	Disease index
Fully Mature	6.6667 A
Maximum fruit size	0.6222 A
Just before reaching maximum fruit size	0.6667 A

Means followed by the same letter in the row are not significantly different (P>0.05). Each data point represents the mean of at least 45 data values.

Disease index;

0- No disease
1- 10% disease
2- 11 - 20% disease
3- 21 – 30% disease
4- More than 30% disease

Table 4.7.2 Mean disease severity index during the storage period.

Day	Decease index
1st	0.0000 A
4th	0.0000 B
7th	1.9556 B

Means followed by the same letter in the column are not significantly different by LSD (P>0.05). Each data point represents the mean of at least 45 data values.

Disease index;

0- No disease
1- 10% disease
2- 11 - 20% disease
3- 21 – 30% disease
4- More than 30% disease

When the disease index level 3 was considered those fruits cannot be consumed hence considered as loss. Table 4.7.3 shows that fully mature and just before reaching maximum stages causes higher level of disease development resulting in very high postharvest losses. The postharvest losses are minimum at maximum fruit size stage. It was observed in this experiment. Although Anthracnose is a latent infection disease the incidence can be managed if the fruit is harvested at the maximum stage. In addition this study confirmes that the higher severity of Anthracnose causes postharvest loss of avocado. It causes to reduce the quality of fruit other than the quantity.

Table 4.7.3 Percentage of postharvest loss of avocado due to the diseases.

Maturity stage	% of postharvest loss
Mature fully	33.33%
Maximum size	26.66%
Just before reaching maximum	33.33%

GENERAL DISCUSSION

Results shows that fruits harvested with stalks attached or stalk detached had no effect on weight loss. There may be varietial differences that effects weight loss of fruits.

Higher disease severity was observed in stalk detached fruits. The removal of stem end had no significant effect on disease severity of avocados during storage. On visual examination there was a clear different among stalk attached and detached fruits.

Highest susceptibility to disease and less Visual Quality Rating (VQR) of fruits was observed in stalk detached fruits. However, the quality of fruits was declined day by day. VQR in avocados shown in the experiment confirms stalk attached to the fruits were better than detached. In addition, it was observed that the stem end rot is a disease, which causes severe postharvest loss of avocado.

Results showed that the fruits harvested at fully mature stage had significantly higher weight loss. The lowest weight loss was observed in maximum fruit size stages of avocado. In addition, the lowest disease severity was observed in maximum fruit size stage. However, in 2nd experiment stem end rot was not common during the storage. Non occurrence of stem end rot may have an effect on variety. Presence of Antharacnose is the main problem in storage.

Best visual quality rating of fruits was in the stage of maximum fruit size. Fully mature avocados were observed with lowest quality during the storage period because fully mature avocados became over ripened and it causes more susceptibility to diseases. However the maximum size of fruits had good eating quality as well as good keeping quality.

Based on these results, avocados must be harvested at maximum stage of maturity and stalk attached is essential in order for better postharvest behaviour of avocado.

CHAPTER 5

CONCLUSION

The complete removal of the stem end (stalk) from the fruit is the method currently being practised in the market. If avocados are harvested with stalk detached, quality of avocado will be poor. In addition, harvesting the fruit with stalk detached lead to high susceptibility to diseases (Mainly stem end rot) and very high postharvest loss of avocado. When Avocados are harvested with stalk attached to the fruits they gave highest quality, best postharvest behaviour and lowest postharvest disease occurrence at room temperature (27°C – 29°C). They were not susceptible to different kind of damages, specially stem end wounds.

Postharvest behaviours of avocados depend on the kind of variety. In addition to that storage period of avocado directly affected the quality changes and disease severity. Within the 3 – 4 days after harvest, quality and quantity declines rapidly and diseases of the fruits increased.

However avocados harvested with stalk attached to the fruit gave good quality fruits with lesser disease incidence (specially stem end rot) and best postharvest behaviour of avocado than stalk detached. Considering the harvesting, the best method to be practised is stalk attached to the fruit. Stalk attaching to fruit cause reduction of postharvest loss of avocado down to 20 – 26% from observed 40% when stalk was detached.

Avocado like fruits are susceptible to different kind of damages at, and after harvest. Such damage is a major cause of loss of quality / quantity or both. In order to reduce these losses, it is necessary to know the maturity stage of avocado. The commercial practice of harvesting avocado is to harvest all the fruits of all stages at the same time.

Avocados harvested at immature stage causes unacceptable eating quality, shrivelling and soften unevenly. In addition high susceptibility to diseases occurred in avocados harvested at just before reaching maximum fruit size and over ripen fruits (fully matured fruit become over ripen within 7 days).

However fully mature fruits ripen properly within 3 – 4 days. Avocado firmness correlates well with fruit ripeness, expected storage time and diseases incidence (Specially Stem end rot and Anthracnose). Over ripen avocados decay rapidly. More ever fully mature fruits gave higher eating quality but less keeping quality.

Maximum fruit size stage of avocados softens when placed several days (5 – 6 days) at room temperature (27°C – 29°C) after being picked. It gave good quality fruits with minimum disease incidence. A postharvest loss due to the diseases was minimum at this stage and hence best keeping quality was obtained. Finally it should be emphasized that it is commercially important to identify the maximum maturity (i.e. the maturity index) that ensures less diseases incidences.

Further studies and Recommendation.

1. Pruning should be practised to the plant and studied to see whether it results in higher disease resistant.
2. Should study the relation ship between disease occurrence in fruits and fungicide application on flower.
3. Micro organisms causing diseases should be isolated and their characteristics should be studied.

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APPENDIX

Analysis of Variance Procedure for % of weight loss of avocado (Experiment 1)

The SAS System 16:33 Friday, December 26, 1997 38

Number of observations in data set = 180

Dependent Variable: WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	39.44769098	13.14923033	6.58	0.0007
Error	56	111.94236027	1.99897072		
Corrected Total	59	151.39005125			

R-Square	C.V.	Root MSE	WEIGHT Mean
0.260570	12.60762	1.413850	11.21425

Dependent Variable: WEIGHT

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	3	39.44769098	13.14923033	6.58	0.0007
STALK	1	0.95785935	0.95785935	0.48	0.4917
TRT*STALK	0	0.00000000			

T Grouping	Mean	N	TRT
A	12.0596	15	22
A			
A	11.9631	15	21
B	10.6216	15	12
B			
B	10.2127	15	11

T Grouping	Mean	N	STALK
A	11.3406	30	d
A			
A	11.0879	30	a

Analysis of Variance Procedure for visual quality rating of avocado

Number of observations in data set = 180

Dependent Variable: QUALITY

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	518.13888889	86.35648148	81.19	0.0001
Error	173	183.99861111	1.06357579		
Corrected Total	179	702.13750000			

R-Square	C.V.	Root MSE	QUALITY Mean
0.737945	14.96442	1.03129811	6.89166667

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	3	8.19305556	2.73101852	2.57	0.05
STALK	1	5.51250000	5.51250000	5.18	0.0240
DAY	2	504.433333	252.216666	237.14	0.0001

T tests (LSD) for variable: QUALITY

Means with the same letter are not significantly different.

T Grouping	Mean	N	TRT
A	7.2111	45	11
A			
B A	6.9222	45	21
B A			
B A	6.8111	45	12
B			
B	6.6222	45	22

T Grouping	Mean	N	STALK
A	7.0667	90	a
B	6.7167	90	d

T Grouping	Mean	N	DAY
A	8.5750	60	2
B	7.4917	60	6
C	4.6083	60	10

Analysis of Variance Procedure for disease index (stem end rot)

Number of observations in data set = 180

Dependent Variable: INDEX

source	DF	Sum of Squares	Mean Square	F Value	Pr
Model	6	23.90000000	3.98333333	6.64	0.0001
Error	173	103.76111111	0.59977521		
Corrected Total	179	127.66111111			

R-Square	C.V.	Root MSE	INDEX Mean
0.187214	340.0031	0.77445155	0.22777778

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	3	3.21666667	1.07222222	1.79	0.1513
STALK	1	2.00555556	2.00555556	3.34	0.0692
DAY	2	18.67777778	9.33888889	15.57	0.0001

T tests (LSD) for variable: INDEX

Means with the same letter are not significantly different.

T Grouping	Mean	N	TRT
A	0.4444	45	12
A			
B A	0.2222	45	22
B A			
B A	0.1556	45	21
B			
B	0.0889	45	11

T Grouping	Mean	N	STALK
A	0.3333	90	d
A			
A	0.1222	90	a

T Grouping	Mean	N	DAY
A	0.6833	60	10
B	0.0000	60	6
B			
B	0.0000	60	2

Analysis of Variance Procedure for disease index (Anthracnose)

Number of observations in data set = 180

Dependent Variable: INDEX

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	76.50000000	12.75000000	19.61	0.0001
Error	173	112.49444444	0.65025690		
Corrected Total	179	188.99444444			

R-Square	C.V.	Root MSE	INDEX Mean
0.404774	163.0891	0.80638508	0.49444444

Source	DF	Anova SS	Mean Square	F Value	Pr > F
TRT	3	7.61666667	2.53888889	3.90	0.0099
STALK	1	0.00555556	0.00555556	0.01	0.9265
DAY	2	68.87777778	34.43888889	52.96	0.0001

T tests (LSD) for variable: INDEX

Means with the same letter are not significantly different.

T Grouping	Mean	N	TRT
A	0.7778	45	12
A			
B A	0.5333	45	11
B A			
B A	0.4667	45	21
B			
B	0.2000	45	22

T Grouping	Mean	N	STALK
A	0.5000	90	a
A			
A	0.4889	90	d

T Grouping	Mean	N	DAY
A	1.3667	60	10
B	0.1167	60	6
B			
B	0.0000	60	2

Analysis of Variance Procedure for % of weight loss of avocado (Experiment 2)

Number of observations in data set = 45

Dependent Variable: WEIGHT

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	24.2490977	12.12454889	8.92	0.0006
Error	42	57.06473333	1.35868413		
Corrected Total	44	81.31383111			

R-Square	C.V.	Root MSE	WEIGHT Mean
0.298216	13.89893	1.165626	8.386444

T tests (LSD) for variable: WEIGHT

Means with the same letter are not significantly different.

T Grouping	Mean	N	STAGE
A	9.3733	15	1
B	8.1720	15	3
B			
B	7.6140	15	2

Analysis of Variance Procedure for visual quality rating of avocado

Number of observations in data set = 135

Dependent Variable: VQR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	542.31111111	35.57777778	225.90	0.0001
Error	130	78.02222222	0.60017094		
Corrected Total	134	620.33333333			

R-Square	C.V.	Root MSE	VQR Mean
0.874225	10.89432	0.77470700	7.11111111

Source	DF	Anova SS	Mean Square	F Value	Pr > F
STAGE	2	16.93333333	8.46666667	14.11	0.0001
DAY	2	525.37777778	262.68888889	437.69	0.0001

T tests (LSD) for variable: VQR

T Grouping	Mean	N	STAGE
A	7.5333	45	2
B	7.1333	45	3
C	6.6667	45	1

T Grouping	Mean	N	DAY
A	8.8667	45	1
B	8.1111	45	4
C	4.3556	45	7

Means with the same letter are not significantly different.

Analysis of Variance Procedure for disease index (Anthracnose)

Dependent Variable: INDEX

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	114.78518519	28.69629630	69.27	0.0001
Error	130	53.85185185	0.41424501		
Corrected Total	134	168.63703704			

R-Square	C.V.	Root MSE	INDEX Mean
0.680664	98.73696	0.64361869	0.65185185

Source	DF	Anova SS	Mean Square	F Value	Pr > F
STAGE	2	0.05925926	0.02962963	0.07	0.9310
DAY	2	114.72592593	57.36296296		

T Grouping	Mean	N	STAGE
A	0.6667	45	1
A			
A	0.6667	45	3
A			
A	0.6222	45	2

T Grouping	Mean	N	DAY
A	1.9556	45	7
B	0.0000	45	4
B			
B	0.0000	45	1

Means with the same letter are not significantly different

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