EFFECT OF DROPPING HEIGHT DURING FRUIT HANDLING ON THE QUALITY OF SELECTED AVOCADO (*Persea americana* Miller) CULTIVARS

M.Sc. THESIS

BY

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BY

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DEDICATION

This thesis is dedicated to my beloved family my father Negash Mohammed and my mother Sewdat Yassien, and my sister Wobalem Negash, my brother Mr. Asebe Wolde, my husband Mr. Oumer Sherieff, my children's Amriya Negash and Tabtadotsiya Oumer and other family members for their encouragement, continuous support for the success of my life and their affection and love.

STATEMENT OF THE AUTHOR

I, the undersigned, hereby declare that the thesis entitled "Effect of Drop Heights During Handling on the Quality of Selected Avocado Cultivars" is my actual work and all sources of materials used for this thesis have been duly acknowledged. This thesis is submitted in partial fulfillment of the requirements for M.Sc. degree at Jimma University College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to borrowers under rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

The author Hania Negash was born from her father Mr. Negash Mohammed and mother Mrs. Sewdat Yassien at Jimma town, Oromia Regional State, on March 08, 1983. She attended and completed elementary school at Jimma Hermata Elementary School (1995-2002), High school at Jimma Secondary School (2003-2005) and Preparatory at Jimma Preparatory School (2006-2007). In September 2008, she joined Jimma University College of Agriculture and Veterinary Medicine and graduated with BSc degree in Horticulture in June 2010. Then she has worked in Jimma Zone, Oromia Regional state at Dandi Boru University College for one year and three months (September 2010 to September 2011). In September 2011, she joined the School of Graduate Studies of Jimma University to pursue her graduate study leading to MSc degree in Postharvest Management.

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LIST OF ABBREVIATIONS AND ACRONYMS

a*	redness
A.O.A.C	Association of Official Analytical Chemists
ANOVA	analysis of variance
b*	yellowness
CRD	Completely Randomized Design
DH	drop height
DM	dry matter
E	Equivalent weight of acid
FAO	food and agriculture organization of the United Nations
JUCAVM	Jimma University college of Agriculture and Veterinary Medicine
L*	lightness
LSD	Least Significant Difference
MARC	Melkasa Agricultural Research Center
Ml	milliliter
N	Normality
NaOH	Sodium Hydroxide
P:P	Pulp to peel ratio
PH	power of hydrogen
PL	pectolytic
PLW	physiological loss of weight
SAS	Statistical Analysis System
SW	weight of samples
TA	Titratable Acidity
TA-XT	texture analyzer
TSS	Total Soluble Solid
USAID	United State Agency for International Development
Wa	weight of extraction flask after extraction
Wb	weight of extraction flask before extraction
Wf	weight of fat

EFFECT OF DROPPING HEIGHT OF FRUITS DURING HANDLING ON THE QUALITY OF SELECTED AVOCADO (*Persea americana* Miller) CULTIVARS

ABSTRACT

Avocado fruit experiences different problem from that of most other fruits, because ripe avocado fruits are very perishable. Postharvest mishandling such as mechanical damage reduced the annual yield of avocado fruit. Fruit quality is adversely affected by bruise damage. One of qualitative aspects is the detrimental effect of impact damage. Losses from postharvest avocado damage are severe in Ethiopia. The dropping height of fruit after harvest to reduce impact damage has been increasingly curtailed by mishandling of fruits at the whole sale, the buyer and the consumer lack of awareness how to handle the fruits, negative public perception regarding the safety of fruit storage and consequent restrictions on selecting cultivars. The objective of this study was to determine the effect of different dropping heights during handling on the Quality of Selected Avocado Cultivars during the storage life of Avocado fruit and to reduce postharvest losses by controlling bruise damage extent. In this research, a stationary device was developed to study fruit mechanical damage. Bruise area was determined by one of impact characteristics (impact energy of the dropping height) and then impact damage was tested in three different dropping heights. The experiment was focused on determining the effect of dropping height on three different avocado cultivars and it was carried out by using impact characteristics method. The treatments consisted of dropping heights (control, 0.79 and 1.58m). Avocado fruits were subjected to impact by means of a stationary device (pole) by allowing free fall to the ground surface and then stored at room temperature. The experimental design for this study was *a 3x3 factorial design arranged in complete randomized design (CRD). The experiment consisted of two factors, three avocado cultivars (Ettinger, Fuerte and Pinkerton), and three different Dropping heights (control, 0.79 and 1.58m) with three replications. Response measurements collected were physiological weight loss (%), pulp to peel ratio (g), firmness(Kgf), total soluble solid (°Brix), titratable acidity (%), dry matter (%),pH(%) , decay/rotting percentage(%),time to ripen(days),crude fat determination(%),peel color(chroma value), storage life (days) and external bruise area(mm). All Dropping heights and cultivar used for this experiment had significant (p<0.05%) effects on most of physico- chemical characteristics evaluated. But had no significant effect on dry matter content from all Dropping height used but not cultivar, Pinkerton Avocado cultivar showed the minimum Dry matter percentage (21.80 %) compared with the other treatments 18 days after storage. It can thus be concluded that among the Dropping height and cultivar used, Bruising can occur at any point from harvesting through to sale and can only be minimized with careful handling that bruise damage of avocado fruit will be reduced by decreasing the dropping heights and selecting the cultivar of the fruits. Pinkerton cultivar at control, 0.79 and 1.58m dropping height proved to be effective during handling test. Dropping at the control reduced the development of mechanical damage, maintained the freshness of the avocado fruits and increased shelf life of Ettinger, Fuerte fruits for up to 18 and 25 days without affecting the physico-chemical properties. Thus, further research efforts are needed to integrate the current findings to be used in integrated damage management in the near future.*

1. INTRODUCTION

1.1. Background

The Avocado (*Persea Americana* Miller) is an evergreen tree of the family Lauraceae with seedling plants reaching 20m in height with small to large, single seeded fruits having yellow to yellowish green butter-like flesh. Mature fruits vary in color and may be green, purple or red. It is an important fruit with a high market value, but with relatively short storage life.

Many defects originate or increase because of an inadequate handling of fruits from harvest to consumption. Friction damage, which is characterized by an oxidation of the tissue that later inclines downward and becomes necrotic, is one of the most frequent problems during harvest, and it has been estimated to be present up to 78% of the fruits. Mechanical damage accelerates water loss and disrupts superficial arrangement of the tissue allowing faster gas exchange. Cuts break completely the protective layer of the fruit and expose the tissue directly to the environment (Zamora *et al.,* 1991; Morales, 2001).

As a general rule, maximum fruit quality is determined at harvest (Hofman *et al.*, 2002). Post harvest handling can at best maintain fruit quality but cannot improve. Mechanical damage to fruit is a major source of postharvest losses in many fruit (Kays and Paull, 2004) including avocados. Although avocado fruits are harvested when green and hard, bruising can be a major cause of quality loss at the retailers hand (Hofman *et al.*, 2002). Bruising can occur at any point from harvesting to sale and can only be minimized with careful handling. The amount of bruising damage that occurs on a fruit depends on the ripeness of the fruit, the distance the fruit is dropped and the mass of an object hitting the fruit (Arpaia *et al*., 1987). Depending on the force of the impact, when bruised hard green fruits can be damaged both internally and externally. The mechanical damage to the skin caused by bruising can serve as an entry point for pathogens that cause postharvest rots (Everett, 2001) especially after rain (Pak, 2003). In addition in most fruits the wound site serves as an ethylene source promoting premature ripening (Kays and Paull, 2004). Although it is recommended that avocado fruits be handled gently it is not known how far the fruit can be dropped after harvest before damage occurs. It is also not well understood how the handling of the fruit at harvest and in the pack house cause damage to the fruits leading to an increased expression of ripe rots.

Postharvest losses of avocado fruits can occur at farm level and in the market places due to inappropriate handling practices, occurrence of postharvest diseases, and so on. Studies conducted in different regions of the world have documented the contributions of inappropriate handling practices and postharvest diseases on the extent of postharvest losses of avocado fruits. However, there is less information about the effects of harvesting and postharvest handling practices on the development of fungal diseases associated and quality loss with avocado fruits such as avocado bruise damage and the extent of postharvest loss attributed to this damage. Therefore, collecting and analyzing information regarding the postharvest practices affecting the fruit quality in steps of the postharvest handling of avocado is very important for further improvement, management and promotion of the products. It is therefore assumed that, since harvesting, postharvest practices like transporting and storage system varies from farm to farm and location to location, the damage of avocado by drop and its bruise development may also vary. In addition, consumers have become more health-conscious regarding safety aspects concerning the handling of perishables. Therefore, not only the 'external aspect' but also the absences of hazardous substances have become imperious issues for buyers. A study was conducted to determine the cumulative effects of handling on postharvest quality of avocado fruits and to characterize the relationship between drop height and fruit quality after storage with the following objectives.

1.2. General Objective

- To evaluate the effect of dropping height during handling on the quality of selected avocado cultivars

1.3. Specific Objective

- To identify a relatively optimum drop height during handling of avocado fruits without compromising their shelf life and fruit quality

2. LITERATURE REVIEW

Avocado (*Persea americana* Mill.) is a tropical fruit that belongs to the family *Lauraceae* and is native to tropical America (Griesbach, 2005). The avocado tree is evergreen, though heavy leaf fall may occur during profuse blossoming and when the tree is affected by root rot. The growth habit varies from tall and upright to well-shaped and spreading. The avocado tree exists in a dynamic environment and therefore can respond to changes to that environment in an interactive fashion (Arpaia, 2004). Avocado tree grows throughout the year but fruit bears between March and September. Avocado is grown under diverse climatic conditions. Fifty seven countries are involved in avocado production but Mexico is the major producer and 97% is consumed locally (Maria, 2007 and Musa, 2010). Countries that compete on the European market for avocado fruit export are South Africa, Israel, Spain, Mexico and Kenya (Musa, 2010). In 2008 and 2009, approximately 64% of South African produced avocados were exported (DAFF, 2010). It is highly nutritious and contributes nearly 20 vitamins, minerals and phytonutrients to the diet, including 8% of the Daily Value for dietary fiber and 4% of the Daily Value for potassium, per serving (28.3g). Edossa (1997) reported that avocado fruit was unknown to consumer in southwestern part of Ethiopia in general about fifteen years back.

Ethiopia is the 10th major producer and the 6th leading consumer of avocado in the world (FAOSTAT, 2010). The crop was first introduced to Ethiopia in 1938 by private orchardists in Hirna and Wondogenet and gradually spread throughout the country (Woyessa and Berhanu, 2011 and Zekarias, 2010). The crop now stands second in total volume of production, next to banana, in Ethiopia (Joosten, 2007). With annual production of 80,000 tons, the fruit is now produced by more than half a million farmers countrywide; and its area has extended more than 7000 hectares of land (FAOSTAT, 2010).

Avocado is now being widely distributed in the country from lowland to highland areas (1000-2300 m.a.s.l) where there is no frost hazards. Presently, there is a great demand for avocado in the southwestern part of the country (Edossa, 1997). This demand is very high particularly at Jimma zone**.** Assessment done by Woyessa and Berhanu (2011) in Mana district showed that there has been an increasing trend of avocado production in the last several years. But its production is too traditional and poorly supported by scientific recommendations due to failures in institutional, social and economical factors. Its marketing activity is poorly linked along the channel (harvesting, product sorting, grading, packing, transporting and marketing) which results in postharvest loss of the product.

A significant proportion of postharvest loss of agricultural produce is experienced in Ethiopia (Admass, 2004). Production is limited by poor pre- and post-harvest handling practices, low quality planting materials, poor crop management practices; poor infrastructure, poor market information, pests and diseases infestation and limited local utilization (MoA, 2008). Avocado fruits incur large losses of about 40% during postharvest handling (Wasilwa et al., 2004) leading to reduced fruit quality (Anjum and Ali, 2004). Postharvest losses are reported to occur between the time of harvest and shipment to its final destination due to poor postharvest handling practices (Anjichi et al., 2006). This means that almost half of what is produced never reaches the consumer, thus the effort and capital required to produce the fruits are lost (Kader and Rolle, 2004). Additionally, the wastage not only affect the growers' income, but also reduce the local market volumes, food required to feed the country's population and it is also a waste of resources used in production.

Harvesting usually started when fruits start to drop, which is principal maturity index in Jimma areas (Berhanu, 2011). Assessment done in this area further depicted harvesting is largely executed by child labor climbing on tree where use of picking hooks, shaking of trees and knocking down fruits are exercised at lower rate (Berhanu, 2011). However this practice has usually resulted in fruit dropping that may cause physical injury which creates favorable condition for disease occurrence. Fresh fruits are highly susceptible to mechanical injury owing to their tender texture and high moisture content (Adugna et al., 2011).

Fruits of avocado are sold in an open market being exposed to direct sunlight leading to a very hot condition that increases the deteriorations after harvest. If they are exposed to undesirable environmental conditions like high temperatures during transportation and marketing soften in tissue and bruise easily, causing rapid microbial infection. Owing to the lack of natural defense mechanisms in the tissue, the microorganisms spread rapidly causing fruits unfit for consumption (Adugna *et al*., 2011). The avocado (*Persea americana*) belongs the family *Lauraceae* and is a native plant of Southern Mexico and Central America. Historical records of the usage of the plant exist from 7000 B.C. of its cultivation from 6000 B.C. and continuous use in all the well known archeological sites of Mexico (Kuinimeri, 2011). Early European travelers in the sixteen century found avocado in cultivation and distributed throughout Central America, Northern and South America. Distribution to the Africa and Asian tropics occurred during the 1700's and 1800's (Nakasone and Paull, 1998).

The avocado is botanically classified into three races: 1) West Indian (WI), *Persea americana* Mill. var. americana, tropical with large variably shaped fruit and lower oil content; 2) Mexican (MX), *Persea americana* Mill. var. drymifolia Blake, semi-tropical with smaller elongated thin-skinned fruit and higher oil content; and 3) Guatemalan (G), *Persea nubigen*a var. guatemalensis L., subtropical with mostly round thick-skinned fruit and intermediate oil content (Bergh, 1992). Many of the commercial cultivars are hybrids of the three races. There is great variability in fruit traits not only between races but between cultivars within a race. One of the most distinct differences between cultivars is the peel color when ripe. The peel of some cultivars changes from green to black or purple with increasing maturity or ripening (Kasim, 2012). The well known variety 'Fuerte' is a Guatemalan-Mexican hybrid, while 'Hass' is of Guatemalan origin (Maria, 2007). And Fuerte variety is tall tree and is a hybrid and produces a shiny green, round pear shaped, large to very large fruits. Oil content around 18-26%, good flesh but also tends to bear fruits in alternate years (Kuinimeri, 2011). Private orchard owners in *Hirna* and *Wendogenet* areas first introduced avocado to Ethiopia in 1938 GC (Birhanu, 2011). Gradually, its cultivation spread nationwide with satisfactory adaptation to different agro-ecologies. Avocado is now being widely distributed in the country from lowland to highland areas (1000-2300 m.a.s.l) where there is no frost hazards (Zakarias, 2010). The demand for avocado is very high at Mana District, which is located in the vicinity of Jimma town**.** Assessment in Mana district showed that there has been an increase trend of avocado production in the last several years (Woyessa and Berhanu, 2011). The study indicated that the average amount of avocado tree grown by individual farmer before 10 years and 5 years were 5.2 and 15.3, respectively. Currently individual farmer owned avocado trees around his garden or field with minimum and maximum of 8 to 400 avocado plants, respectively. This indicates that on average there were 85% increase of avocado plant over the avocado owned by individual farmers before 10 years (Woyessa and Berhanu, 2011).

Avocado flowers carry both male and female reproductive organs. Each flower opens twice over a two-day period, the first day as a female and the second day as a male. This enables the classification of varieties as either an A or a B type flower. Air temperature regulates the opening and closing of flowers. In summary, there are three requirements for a successful fruit set: 1) An overlapping of the flowering stages, 2) Significant insect activity, including bees and 3) Temperatures above 10oC during flowering and for the three days following. Flowering normally lasts for three to four weeks, longer in cooler growing areas. In adverse weather conditions fruits can form without pollination. Such fruits are small and cigar-shaped and are known as 'cukes' or 'cocktails'. In some growing areas the application of a plant growth regulator at flowering has produced less 'necky' and larger sized fruit (Agfact, 2003).

Avocado is a climacteric fruit characterized by a surge (rush) in ethylene production at the onset of ripening. This climacteric increase in ethylene production is associated with hastened ripening. Ripening or softening of avocado does not occur during maturity on the tree, but takes place several days after fruits have been picked. It seems that there is a flow of inhibitive components from leaves to the fruit, preventing fruit from softening on the tree (Werman and Neeman, 1987). Avocado is one of the most rapidly ripening fruits often that completely ripen 5-7 days after harvest (Seymour and Tucker, 1993).

Fruit maturity and picking time are determined according to external markers (color and size), or by measuring oil content and dry matter in the flesh (Werman and Neeman, 1987). Ripening of climacteric fruits involves a series of coordinated metabolic events which alter their anatomy, biochemistry, physiology, and gene expression (Giovannoni, 2001). These alterations affect many characteristics, such as color, flavor and texture of the fruit (Cai *et al*., 2006). Fruit firmness at later picking dates was lower and the rate of softening during storage was faster compared with earlier picking dates (Zauberman *et al*., 1986). Fruit softening is closely connected with cell wall modifications caused by some cell wall degrading enzymes (any of numerous complex proteins that are produced by living cells and catalyze specific biochemical reactions at body temperature) (Fischer and Bennett, 1991). Moreover, softening is an important part of the ripening process, and it is well documented that change in cell walls accompany fruit softening (Brummell and Harpster, 2001).

2.1. Importance of Avocado Fruits

Bergh (1992) described the avocado fruit to be nutrition-rich while others in the industry call it a functional food due to its additional health benefits from certain phytochemicals. It contains high amounts of vitamins A, B, C, E, and other nutrients like folacin, niacin, iron (Fe), magnesium (Mg), folate, antothenic acid and contains 60% more potassium than bananas. Most of these nutrients are deficient in most typical diets and are all abundantly present in avocado. The fat content of avocado is another valuable aspect of the fruit. More than 70% of its fat is monounsaturated fat with low levels of polyunsaturated and saturated fat with slight variations according to cultivars and fruit maturity stage (Arpaia et al., 2006). Avocado protein has also been proven to contain all the essential amino acids for human nutrition attributes not provided by any other plant source (Bergh, 1992).

2.2. Quality

Quality is a difficult term to define. This difficultness arises from people being different and individuals having expectations of what they expect and what they like about any particular product. Quality is ‘fitness for purpose’. It is the product state that meets the expectations of the customer/consumer. This state will encompass concepts such as the position of a person in the supply chain from farm to consumer. It will be a function of the financial position as well as the cultural background of the individual purchaser. Whatever happens, the customer is always right. If producers do not recognize these needs and desires, then a decline in consumption of fresh fruits and vegetables could occur (Shewfelt, 1999; Shewfelt and Henderson, 2003). Quality is made up of many attributes, both intrinsic and extrinsic. These attributes will vary depending on the expectations and memory of the consumer. Intrinsic features of the product include key external attributes such as color, shape, size and freedom from defects. In addition, internal attributes include texture, sweetness, acidity, aroma, flavor, shelf life and nutritional value. These are important components of the subjective approach used by the consumer in deciding what to purchase. Extrinsic factors refer to production and distribution systems. These factors include chemicals used during production, package types and their recycling capability, sustainability of production and distribution in relation to energy utilization. These extrinsic factors are likely to influence consumer's decision to purchase rather than to reflect on the actual quality of a product (Jongen, 2000).

2.3. Quality Characteristics and Criteria for Avocado

For avocado, the major quality criteria used during grading are size, skin color, freedom from wounds, blemishes, insect damage (particularly due to caterpillar and thrips scarring), spray residues (most commonly copper) and other contaminants on the skin. When ripe, the key issues are absence of disease (body rot and stem end rots), physiological disorders (flesh graying), and physical damage (bruising). Many of these quality factors are cultivar-dependent and consumer preference for size, shape and color can vary from region to region (Avocado Industry Council, 2007).

Avocados are one of the few fruit that contain significant quantities of oil; sometimes > 30% of fresh weight depending on cultivar and maturity. Oil content is a key part of the sensory quality. Oil quality is very similar to that of olive oil with a high proportion of the oil being approximately 75% monounsaturated, 15% saturated and 10% polyunsaturated fatty acids (omega 6). However, there is variation with race, cultivar, growing region and season. The high mono- and poly-unsaturation, and low saturated content makes this "healthy" oil in terms of effect on heart disease. In addition, avocado oil contains a range of other health-promoting compounds such as chlorophyll, carotenoids, α-tocopherol and ß-sitosterol. These health factors, along with the absence of cholesterol, should be emphasized with consumers since avocados are perceived by some as an unhealthy or "fat" fruit (Arpaia and Hofshi, 1998).

2.4. Harvest Maturity Indices

The flowering period in avocados ranges from about 4 to 14 weeks, depending on cultivar and environmental conditions. Therefore, fruits from the same tree will vary in maturity dates. Determination of the correct harvest time is important because it affects the fruit quality and market life. It is important to pick the fruit when mature, as immature fruits will shrivel and not ripen properly. Determining the appropriate harvest maturity may be difficult and experience is important. Fruit of some avocado cultivars, particularly of the West Indian race, fall from the tree when physiologically mature and must be picked prior to fruit drop. In cultivars from the Guatemalan race and its hybrids, the fruits remain attached to the tree for as long as three or four months after physiological maturity has been reached. Avocados generally do not ripen while they are attached to the tree. Fruits are still hard when mature and ripen only after being picked (Yahia, 2001).

Several indices may be used to determine avocado fruit maturity (Watada *et al*., 1984). The specific dates, weights, and sizes used to determine maturity vary by cultivar. Mature fruits are usually picked at weekly intervals over a period of a month or more, the largest fruits being selected each time. The outer waxy surface of the avocado changes appearance upon fruit maturity. Smoothness of the skin is a reliable indicator of maturity in most cultivars. As the fruits approach to maturity, they develop a smoother skin surface. Also, the glossiness or shine of the fruit surface becomes duller as the fruit reaches maturity. External colour can be used as a maturity index. Maturity at harvest is the most important factor that determines storage-life and final fruit quality. Immature fruits are more subject to shriveling and mechanical damage, and are of inferior flavor quality when ripe. Overripe fruits are likely to become soft and mealy with tasteless flavor soon after harvest (Kader, 1999). The oil and dry matter content of avocado tend to increase fruit maturity while on the tree. The best maturity parameter to be used as maturity index was found to be the calendar date (month from flowering to maturity) the weight to length ratio could be used as simple and cheap method for the determination of optimum time of harvest (Maru et al., 2011). The skin colour of many cultivars changes from green to light green with maturity. Reddish streaks may also appear at the stem end of certain deep green skinned cultivars when the fruit becomes mature. Internally, the seed coat of mature fruit turns brown with maturity. Also, in some loose seeded cultivars, mature fruit produce a hollow sound when tapped. Oil content is used as a maturity index for those cultivars high in oil. Dry matter is also used as an index of maturity for certain cultivars. A strong correlation exists between the percentage of oil and the dry matter content. The dry matter is determined by drying 10 g of chopped fruit tissue in a microwave oven for 5 minutes. Avocado fruits are attached to the tree by a stem (pedicel) that changes in appearance as the fruit matures. The area of the stem nearest the fruit changes in colour from green to brown or black when the fruit is mature. This colour change signals the formation of an abscission layer in the stem indicating the fruit is mature and ready for harvest (Watada *et al*., 1984).

2.5. Harvesting of avocado

Harvesting of the fruit before reaching an optimal point can lead to deficient ripening and quality. On the other hand, when the harvest of the fruit is carried out after the optimal point, its post-harvest life could be diminished. In order to determine this optimal harvest point, two quantitative maturation and harvest indexes are used: oil and dry matter contents. However, other complementary indices can be considered, such as the size of the fruit and the appearance of the seed skin (Yahia, 2001). The avocado is unique in the way it ripens. It matures on the tree but does not ripen until it is picked. This characteristic has the advantage of holding the crop on the tree and making the time of harvest less critical. Fruit picked too early shrivels and lacks quality mature fruit has the following characteristics: The fruit stem becomes more yellow, when the fruit is cut and the seed removed, the seed coat is dry and does not stick to the flesh; it is a dark brown color, dark-skin cultivars will show a change from green to purple. Avocados are harvested by hand using ladders, fruit pickers and picking poles. Harvested fruits can be placed in the shade place, and care should be taken to do not drop fruit as bruising will occur.

2.6. Ripening

Fruit ripening is the result of a complex of changes, many of them probably occurring independently of each other. The following are some major changes that occur in most avocados, during ripening (Ben-Yehoshua, 1969). Peel and pulp color changes, Conversion of starch into sugar, Changes in pulp to peel ratio (and ease of peeling), Changes in pulp firmness or pulp softening, Changes in total soluble solids content, Changes in pulp PH and total titratable acidity, changes in peel and pulp moisture and dry matter content, changes in respiration rate and ethylene production (Orchard, 1997).

During ripening, most fruits undergo many physical and chemical changes after harvest that determines the quality of the fruit purchased by the consumer. Ethylene is a plant hormone that is naturally produced by avocados. Both respiration and ethylene formation are, predominantly, responsible for the ripening of avocados (Wu *et al*., 2011). Avocado being as climacteric characterized by a rush in ethylene production at the start of ripening. The respiration of avocados follows three characteristic climacteric phases, pre- climacteric minimum of least respiration, climacteric maximum of highest respiration and a post-climacteric phase synonymous with a decline in respiration (Perez *et al*., 2004). It is during the pre-climacteric and climacteric phases where much of the changes associated with ripening occur (Perez *et al*., 2004). An increase in the respiration rate hastens senescence contributing to flavor loss and reduced dry weight (Workneh *et al*., 2011b). Therefore, different handling methods, especially those associated with lowering respiration rates should be favored (Kasim, 2012).

2.7. Storage of avocado

When avocado reaches the packing house, special care should be taken so that different batches will not mix up. At the same time, the characteristics of the particular cultivar are verified (Sánchez-Pérez, 2001). The response of avocado to storage temperatures varies according to temperature ranges, as follows: 10 to 25°C: the fruit softens faster as storage temperature increases. 5 to 8°C: softening is controlled, and it will only occur if the fruit is transferred to higher temperatures. 0 to 4°C, softening at these temperatures is limited by time, due to the risk of chilling injury. However, recommended storage conditions may vary according to the avocado cultivar. Optimum storage conditions vary by cultivar, growing conditions, time in the season (maturity) and length of storage required. However, in general, unripe avocados should be stored at 5 to 12 ºC with RH of 85 to 95% (Bower, 1986).

2.8. Main causes of poor quality avocado fruits

2.8.1. Pre-harvest

The primary pre-harvest factors are climate, nutrition and plant growth regulators (PGRs), soil quality and management, rootstock, irrigation, pruning and crop load manipulation operate at least in part through the primary factors (MonseIise and Goren, 1987).

The main causes of pre-harvest loss are:

Ambient heat exposure: Ferguson et al., (1999) observed that predominant pre-harvest factor influencing postharvest quality of avocados to be ambient temperature during growth. This was confirmed by Woolf et al., (1999) who demonstrated that the side of the avocado exposed directly to sunlight while still on the tree was able to withstand higher temperatures during postharvest treatments compared to the shaded side. Avocados exposed to high ambient temperature on the field also demonstrated a tolerance to low postharvest temperatures and external chilling injury (Woolf and Ferguson, 2000).

Water stress: Water stress reduces the internal quality of avocados due to the increased activity in polyphenol oxidase leading to browning of the flesh which favor fungal pathogens (Kasim, 2012). As Yahia (2002) reported lower concentrations of calcium found in water stressed fruit had resulted in high incidence of physiological disorders (Woolf *et al*., 1999). Excessive water availability can result in larger fruit, reduced flavor and firmness, and more disorders. Low water supply can also reduce fruit Ca concentration, presumably because of increased competition between leaves and fruit for available water. The timing of water stress is also important. Stress during early avocado fruit growth increases maturity bronzing, and fluctuating stress increases the risk of fruit splitting. High moisture loss from fruit during storage and ripening is often associated with higher fruit disease and disorders. Thus, production factors which increase moisture loss during storage may reduce fruit quality (Coates et al., 1997).

Harvesting technique: The time of avocado harvesting contributes to the maturation and expected shelf life. Harvesting too early in the season contributes to low pulp dry matter. This is associated with irregular ripening, a watery texture, flavor less, shriveled, blackened fruit and a low oil concentration (Blakey, 2011). Perez et al (2004) states that harvesting prior to physiological maturity results in irregular softening, a poor taste and higher susceptibility to decay. Generally, if the avocados are not harvested at the appropriate time the quality is compromised and the shelf life shortened (Wu et al., 2011).

Nutrition and plant growth regulators (PGRs): Plants require at least 16 elements for normal growth and for completion of their life cycle. Those used in the largest amounts, carbon, hydrogen and oxygen, are non-mineral elements supplied by air and water. The other 13 elements are taken up by plants only in mineral form from the soil or must be added as fertilizers (Hodges, 2007). Plants need relatively large amounts of nitrogen, phosphorus, and potassium. These nutrients are referred to as primary nutrients, and are the ones most frequently supplied to plants in fertilizers. The three secondary elements, calcium, magnesium, and sulfur, are required in smaller amounts than the primary nutrients. Calcium and magnesium are usually supplied with liming materials, and sulfur with fertilizer materials (Hess *et al.*, 2002). Several minerals are known to influence quality, the most notable of these being Ca. Calcium applications or high fruit Ca concentrations are often associated with increased firmness, less disease, chilling injury (Cl), physiological disorders and blemishes such as skin splitting, and slower ripening. High fruit Ca also reduces weight loss during storage, which is often linked to improved storage performance. Manipulation of fruit Ca can be difficult. Responses to soil and spray applications of Ca can be variable and often depends on fruit type, the form of Ca used, and the concentration and frequency of application (Coates et al., 1997).

Plant growth regulators (PGRs) are intimately involved in plant development, and external applications of PGRs during fruit development can have important effects. The most important effects have been obtained with gibberellins (GAs) and their inhibitors (e.g. Cultar®), and cytokinins. Generally, GAs and their inhibitors influence fruit quality through effects on competing vegetative growth, fruit Ca through reduced competition with vegetative growth during the fruit growth period. High abscisic acid (ABA) in fruit may be related to increased disorders (Cutting et al. 1988), so production factors which increase fruit stress during growth should be avoided.

Rootstock: Roots of avocado fruits should usually very well developed extensive or deep root systems to take advantage of superficial rainfall or to tap deep water reserves. Thin cortex, therefore creates small distance between soil water and xylem in the vascular tissue. Vascular tissue often contains well developed xylem which allows rapid transport of water following absorption. Water absorption in some species of giant cacti is accelerated by hydrophilic colloids which accumulate in their root cortex. These reduce the water potential of the root's tissue, accelerating water uptake by osmosis (Shewfelt, 2003).

Pruning and crop load manipulation operate: Little pruning is required after planting as avocado trees generally shape themselves. For the first two years the strong growing tips are pinched out to promote side shoots and a bushier and more compact tree. Limbs causing overcrowding and shoots arising from below the graft union should be removed. It is important to avoid a weak crotch or a divided trunk. Since the avocado is a rainforest tree its growth is rapid if left unpruned. Furthermore, they have terminal flowering and in some areas a long cropping cycle. These factors present a problem in managing the canopy once trees settle into regular cropping. However, there are some options available to growers to regulate tree canopy size, including tree removal, selective limb removal, staghorning and mechanical hedging. Most avocados don't need a lot of pruning. However, pruning avocado trees can be beneficial in some cases. Pruning these trees is different than pruning other trees, so there are a few things that should know beforehand. In general, avocado trees require an abundance of healthy foliage to assure high yields. In most cases such abundance is best achieved by pruning only when absolutely necessary. Since avocado trees grow irregularly and different varieties have different growth habits, pruning methods will vary. The yield of bearing avocado trees is in direct proportion to the amount of healthy wood and foliage on the tree. Heavy pruning does not increase fruit production but reduces it by stimulating new vegetative growth at the expense of fruit production. Balance is one of the most important things that need to know about pruning avocado trees (CAS, 1962).

Crop Load has generally a direct relationship between leaf to fruit ratio and fruit size. Crop load can also affect ripening patterns, possibly through an interaction with fruit maturity and mineral (especially Ca) concentrations. For example, lower leaf: fruit ratio in banana leads to a reduced green life as a result of fruit taking a longer time to attain minimum marketable size. Sugars and SS concentrations can be increased at higher leaf: fruit ratios because of reduced competition for available carbohydrates. Firmness can be reduced, possibly through variations in fruit size and Ca. Fruit disorders and disease are generally more severe in fruit from trees with high leaf: fruit ratio or high vegetative vigor, possibly through reduced fruit Ca concentration as often found in these fruit, and their larger fruit size. Vegetative flushing during early fruit growth has been shown to reduce avocado fruit size and Ca concentration, and increase disorders (Coates et al., 1998).

2.8.2. Post-harvest

Chilling injury, Postharvest Pathology, Mechanical damage, Transpiration, Respiration, Ethylene, Physiological reaction

***The main causes of post-harvest loss are*:**

***Chilling injury**:* Temperature is the main environmental factor in the control of produce ripening. Thus, in order to obtain successful results, it is important to handle this factor properly, keeping the fruit under low, specific temperatures that should never be below 0ºC. However, some fruits suffer chilling injury at temperatures over the freezing point. According to Pesis *et al.* (1994), avocado is a subtropical fruit that is sensitive to chill injury when exposed to low temperatures, even if they are over the freezing point (for example, 2 to 4ºC). The main symptoms of chilling injury are black stains in the epidermis and a gray or brown discoloration in the mesocarp. Morris (1982) reported that another symptom is the alteration of internal metabolism, which leads to an increase of the levels of anaerobic respiration and, as a consequence, of abnormal metabolites, resulting in the development of foul taste and odor. However, the effects of chilling injury in avocados is clearly seen only when the fruit is ripe, which in some cases may be too late for marketing effects (Corrales-García, and Tlapa-Rangel, 1999). However, refrigeration slows the speed of biological processes in the fruit, delaying ripening and senescence. In the case of avocado, storage under refrigeration should not exceed 30-40 days. In order to guarantee a higher efficiency in the refrigeration treatment, a pre-cooling process is recommended (Téliz, 2000; Morales, 2001).

Fungal damage*:* Anthracnose (*Colletotrichum gloeosporioides*) is the cause of a fungal infection that is considered of major importance. Besides the damages it causes in the production of avocado, it also reduces the fruit quality during its transport, storage and marketing, where it causes the largest losses. The damages in a green fruit begin with discolored circular areas. The fungus penetrates the fruit and makes it rot. The lesions are of variable size, and of a dark brown color. In the surface of lesions, cotton-like spots appear. It is favored by high relative humidity, damaged fruit and foliage, and when branches touch the ground. The chemical control is made with copper-based fungicides that are also used as a preventive measure on leaves and fruit still on the tree (Téliz, 2000).

Mechanical damage: Many defects originate or increase because of an inadequate handling of the fruits from harvest to packaging. Friction damage, which is characterized by an oxidation of the tissue that later inclines upward and becomes necrotic, is one of the most frequent problems during harvest, and it has been estimated to be present up to 78% of the fruits. Mechanical damage accelerates water loss and disrupts the superficial arrangement of the tissue allowing a faster gas exchange. Cuts break completely the protective layer of the fruit and expose the tissue directly to the environment (Swarts, 1984).

The damage is more notorious in fruits along the packaging process, mainly due to inadequate handling that affects the number of fruits with export quality. Zamora-Magdaleno *et al.* (1999) explained friction damage before harvest as a result of fruit friction during growth or as a result of friction with leaves or small branches. Damage proportion at this point may be from 2 to 35%, and increased at the packinghouse from 10 to 62%. Mechanical damage occurs in the postharvest handling system primarily in two ways: impact forces and compressive forces. Excessive impact occurs during harvesting, grading, handling and transportation (Shafiur, 1999). Bruises are not always immediately visible but they become noticeable during subsequent handling shelf life (Van *et al*., 2006). The resistance to mechanical damage is given by the composition of the cells of the epidermis and the arrangement of the vascular tissue. A strong, elastic peel will not present any damage as a result of mishandling (Morales, 2001).

Physiological reaction*:* Losses in fruit quality are mostly due to its relatively high metabolism activity during storage (Fattahi *et al.*, 2009). During normal ripening, the peel loses water to both the atmosphere and the pulp leading to higher weight loss, desiccation of the fruit and uneven ripening. During postharvest handling and storage, fresh fruits and vegetables lose moisture through their skins via the transpiration process. Commodity deterioration, such as shriveling or impaired flavor, may result if moisture loss is high. In order to minimize losses due to transpiration, and thereby increase both market quality and shelf life, commodities must be stored in a low temperature, high humidity environment (FAO, 1995).

In addition to proper storage conditions, various skin coatings and moisture-proof films can be used during commodity packaging to significantly reduce transpiration and extend storage life (Ben-Yehoshua, 1969). Metabolic activity in fresh fruits and vegetables continues for a short period after harvest. The energy required to sustain this activity comes from the respiration process (Mannapperuma, 1991). Respiration involves the oxidation of sugars to produce carbon dioxide, water and heat. The storage life of a commodity is influenced by its respiratory activity. By storing a commodity at low temperature, respiration is reduced and senescence is delayed, thus extending storage life. Proper control of the oxygen and carbon dioxide concentrations surrounding a commodity is also effective in reducing the rate of respiration. Harvested fruits and vegetables are exposed to high respiration and transpiration rates and subsequently high weight and quality losses (Fennir, 1997).

i. Transpiration

Transpiration is one of the two major physiological processes that are carried out after fruits and vegetables are harvested (FAO, 2003). Together with respiration, excessive rates of these two processes lead to physical deterioration of fruits and vegetable after harvesting. Transpiration, or evaporation of water from the plant tissues, is one of the major causes of deterioration in fresh horticultural crops after harvest. Water loss through transpiration not only results in direct quantitative losses (loss of saleable weight), but also causes losses in appearance (wilting, shriveling), textural quality (softening, flaccidity, limpness, loss of crispness and juiciness), and nutritional quality. Transpiration can be controlled either through the direct application of post-harvest treatments to the produce (surface coatings and other moisture barriers) or through manipulation of the environment (maintenance of high relative humidity) (FAO, 2003).

ii. Respiration

Despite having been detached from the plant, fruits and vegetables remain as living organs after harvest. Like all living tissues, harvested produce continues to respire throughout its postharvest life. During the process of respiration, carbohydrates are broken down to their constituent parts to produce energy to run cellular processes, thus keeping the cells and organism alive (Silva, 2008). Throughout this process, oxygen is consumed and water, carbon dioxide, and energy are released. Because this process occurs from harvest to table, the carbohydrates stored in the harvested plant portion are continually "burned" as energy to keep the vegetable/fruits alive; as respiration continues, compounds that affect plant flavor, sweetness, weight, turgor (water content), and nutritional value are lost. Thus, reducing the rate of respiration is an important consideration in extending the postharvest life of a fruit or vegetable and optimizing postharvest quality.

Harvested fruits and vegetables of different plants have different rates of respiration; some respire at a faster rate (and thus are more perishable vegetables and fruits), while some respire at a relatively slow rate (less perishable vegetables and fruits). In addition, storage conditions affect respiration, with higher temperatures leading to a faster rate of respiration; for every 10°C rise in temperature, the respiration rate will double or even triple. Because of the significant effect of temperature on respiration, the amount of time a harvested product is exposed to heat should be minimized; the fruit or vegetable should be quickly brought to its optimal storage temperature (Silva, 2008).

Ethylene*:* It is a colorless gas that is naturally produced by plants and functions as a plant growth regulator. In this way, ethylene behaves in the same way as hormones in mammals (Silva, 2008). According to Rmero *et al. (*2007), ethylene triggers specific events during a plant's natural course of growth and development, such as ripening. The presence of ethylene is not always beneficial, especially in terms of postharvest shelf life. The effect of ethylene treatment on quality of avocado fruit, ethylene treated avocados ripened earlier than un-treated avocados. The negative impact of ethylene is that it increases pathogen susceptibility, physiological disorders and senescence, with a net reduction in postharvest life.

Fruits and vegetables may be classified depending on their response to ethylene. Climacteric species produce ethylene as they ripen, and the harvested produce is capable of ripening during the postharvest period. These commodities, such as avocados, apples, banana and peaches, tend to get sweeter and softer after harvest. Non-climacteric plants, such as leafy vegetables, do not continue to ripen after harvest; they will soften and rot, but this is due to moisture loss, decay, and tissue deterioration (Silva, 2008).

In addition to being naturally produced by plants, ethylene is produced by a cultivar of other sources (Silva, 2000). These include cigarette smoke, and natural gas leaks. Even low concentrations of ethylene throughout the postharvest life of a commodity can affect quality, so care must be taken to minimize exposure from both natural sources (i.e. climacteric fruit or veggies (vegetables) being stored with non-climacteric ones) or to artificial sources (engine exhaust, heaters, etc). All ethylene-producing sources should be considered when optimizing postharvest storage conditions as inadvertent (accidental) exposure to ethylene can contribute to loss of quality in some fruits and vegetables.

Postharvest Pathology*:* Rots of avocados are divided into two categories on the basis of their location (Snowdon, 1990). Stem end rots enter the fruit at the stem, or peduncle end of the fruit and move down the fruit resulting in discolored flesh, often with associated browning of the vascular strands (Johnson and Kotze, 1994). Body rots invade through the skin and are generally manifested as circular brown to black spots that may be covered with spore masses in the later stages of infection. Decay penetrates through to the flesh resulting in discrete (isolated) areas of discolored flesh. In cultivars that darken when ripe (‘Hass’), rots may be less obvious externally. Rots are rarely observed at harvest or during storage but can increase rapidly with fruit softening. Where infection pressure is high and physical damage to the skin occurs prior to storage, small soft black circles of infection can occur during storage. These generally spread rapidly outwards after removal from storage.

The causal organisms can vary with growing environment and country. The following pathogens (in order of frequency) have been isolated from decayed California avocados; *Colletotrichum*, *Dothiorella*, *Alternaria* and *Phomopsis* spp (Smilanick and Margosan, 2001). Differences in the pathogens responsible for decay exist among countries, eg., New Zealand versus Australia (White *et al*., 2001; Everett, 1996).

Pre-harvest control methods for postharvest fungal decay include good orchard sanitation (removal of mummified fruit and dead wood) and effective pre-harvest fungicide application such as copper which is widely used in some countries where humid growing conditions prevail Harvesting should not be carried out in the rain or when fruit are wet, and careful handling to minimize skin damage helps to reduce rots. Snap picking of fruit can reduce stem end rot incidence in dry periods but it can result in increased rots in humid growing environments or when harvested in wet conditions.

Perhaps the most important area for reducing rots is that of maintaining good ripe-fruit quality by optimizing temperatures during handling, storage, transport, and ripening. It is also critical not to store fruit for long periods (Hopkirk *et al*., 1994). Postharvest fungicides (Prochloraz, benlate (benomyl) and thiabendazole) are used in some countries, but these are not registered for use in the U.S. (Darvas *et al*., 1990).

Microbiological factors: Fruits are horticultural products having living tissues with continuing metabolism, and thus subject to respiration, water loss and cell softening throughout the post harvest system (Kader, 1997). Since fruits contribute greatly to human health and are often eaten raw there is need to ensure the safety of these produce by addressing common areas of concern in growing, harvesting, sorting, packing and distribution of fresh produce. One of the most common symptom of deterioration result from the activities of bacteria and fungi. Attack by most organisms follows physical injury or physiological breakdown of the commodity. In a few cases, pathogens can infect apparently healthy tissues and become the primary cause of deterioration. In general, fruits and vegetables exhibit considerable resistance to potential pathogens during most of their postharvest life. The onset of ripening in fruits, and senescence in all commodities, renders them susceptible to infection by pathogens. Stresses such as mechanical injury, chilling and sunscald lower the resistance to pathogens (Hershkovitz *et al*., 2005).

2.9. Postharvest treatments to reduce postharvest losses of avocado

Reduction of post-harvest losses can increase food availability to the growing world population, decrease the area needed for production, and conserve natural resources. According to Kader and Rolle (2004), strategies for loss prevention include: (1) use of genotypes that have longer post-harvest-life; (2) use of integrated crop management systems and Good Agricultural Practices that result in good keeping quality of the commodity; and (3) use of proper post-harvest handling practices in order to maintain the quality and safety of fresh produce. In some instances, it is desirable to maintain the fruits in the unripe state to regulate their marketing life, such treatments currently used to prevent decay or preserve texture and color, can compromise aroma quality. Chemical treatment is necessary for pre-cooled fruits because it can reduce the incidence of physiological disease and improve the storage performance. Many kinds of chemical solutions and others are used.

2.10. Lipid Content of Avocado Fruit

Among all fruits, only the olive (*Olea europea*) and the oil palm fruit (*Eleaeis guineensis*) can rival (equal) avocado in oil content (Lewis, 1978). There is great variability in the lipid concentration in the avocado. Lipids in plants have two basic functions; either structural or as a storage mechanism. The structural lipids are present in membranes where they exist forming the lipid bilayer as phospholipids and glycolipids. Lipids constitute an important part of the cell membrane because they are actively involved in membrane exchange processes (Stumpf and Conn, 1987). Thus, structural lipids are present in tissues in relatively small amounts and are therefore consumed as part of the fruit.

Many of the components of the structural lipids in foods will be incorporated into the structural lipids in the body of the consumer (Enser, 1995). The storage lipids are the triacylglycerols present in the avocado mesocarp fat cells or idioblasts (Schroeder, 1953;

Platt-Aloia *et al*., 1983), with around 85 % of the lipids in avocados present in this form (Platt-Aloia and Thomson, 1981). Triglycerides are normally regarded as storage material to provide carbon and energy to other organs such as germinating seeds. Kikuta and Erickson (1968) reported that lipid content tended to increase during storage however, recent research have shown that the lipids are synthesized only during growth and maturation of fruit on the tree (Platt-Aloia and Thomson, 1981; Luza *et al*., 1990) and that the reported increase was due to fruit undergoing dehydration during postharvest handling and storage. Moreover, high activity rates of fat synthesizing enzymes have been reported during development. For instance, Simoni *et al*. (1967) isolated and purified two fat synthesizing enzymes from Fuerte and Hass avocado mesocarp. The biosynthesis of triglycerides in avocado fruit was elucidated by Barron and Stumpf in 1962.

The biosynthetic pathway appears to be essentially the same as in animal tissue. In addition, among the many enzymes reported to be present in the fruit no evidence of a fat degrading system has been found in avocado (Appleman, 1969). Avocado lipids also contain a non-saponifiable fraction, which comprises some flavor compounds such as esters, terpenes, sterols and nutritionally important vitamins (A, C, E). The seed contains 55% of unsaponifiable material (Werman and Neeman, 1987). A complete analysis of the types of lipids in the mesocarp part of mature Fuerte cv. was made by Kikuta and Erickson (1968) using silicic acid chromatography. They found that as much as 86% of the lipid fraction existed as triglycerides while the free fatty acid fraction was very low (0.10%). In the mesocarp, diglycerides were approximately 1.3% and monoglycerides and phospolipids 0.78 and 0.39% respectively.

The lipid content depended on the cultivar and was one of the distinguishing features of the avocado. Kaiser et al. (1992) pointed out that among other functions in the fruit; lipids impart a unique and desirable taste to the fruit.

Avocado is considered to be an important oil fruit and oil content serves as a significant indicator of fruit maturity (Hofman *et al*., 2002a; Ozdemir and Topuz, 2004; Gamble *et al*., 2010; Blakey, 2011). As the fruit matures the concentration of oil within the mesocarp increases as described by Hofman *et al*. (2002a), Ozdemir and Topuz (2004) and Chen *et al*. (2009). This increase in oil results in a reduction in the water by the same amount within the fruit implying that the percentage of total water plus oil remains constant throughout the avocado life (Hofman *et al*., 2002a; Ozdemir and Topuz, 2004). Lee *et al*. (1983) and Chen *et al*. (2009) observed a close correlation between the percentage oil content and percentage dry matter. The maturity index could then be calculated by either the oil content or dry matter.

2.11. Fruit Drop and extent of damage

Damage to the skin immediately after harvest, as a result of the harvesting implement, dropping into crates, over-filling of crates and excess movement of fruit during in-field transport and storage, will result in latex staining, punctures, scars and bruises. During ripening, bruised areas will develop into dark soft regions which become affected by secondary microbial infection (AIC, 2007). Similar effects can occur as a result of poor handling during washing, grading and packing and marketing. Damage can be reduced by taking protective measures throughout the handling procedures. Staff should be trained with harvesting techniques, foam should be included in the base of field crates and crates should contain only one layer of fruit. Stems are to be removed in the field to prevent puncturing or scratching of adjacent fruit. Vehicles used to transport the fruit from the field to pack house should be driven slowly and with care (Shafiur, 1999).

During handling in the pack house, and storage fruits should never be thrown or dropped and in automated (mechanical) operations, all machinery should be padded (lies across) where possible (Van *et al*., 2006). Mechanical injury is one of the major causes of losses in fresh avocado harvesting and packing operations. Injuries caused by rough handling provide ports of entry for decay-causing organisms resulting in fruit decay in marketing and distribution channels. Mechanical damage to fruit during harvesting and on the packing house line will result serious blemishes and defects. The impact of the latter is usually manifested as decay at wholesale and retail outlets or in the hands of the consumer. This usually lowers grower and packer returns due to price adjustment, reduced sales and loss of customers, which is difficult to measure and more difficult to overcome (Bower, 1986). It is, therefore, important that fruit injury caused by abrasion, dropping or shearing of fruit during harvesting and in the packinghouse be minimized to reduce decay and assure good arrival quality.

The key to such reduction is careful evaluation of harvesting, hand1ing and packing procedures. This must be followed by taking the necessary corrective measures to ameliorate (upgrade/improve) those conditions that lead to fruit injury (McCornack, 1971). Many defects originate or increase because of an inadequate handling of the fruits from harvest to packaging. Friction damage, which is characterized by an oxidation of the tissue that later inclines upward and becomes necrotic (death of tissue), is one of the most frequent problems during handling of the fruits.

Mechanical damage accelerates water loss and disrupts the superficial arrangement of the tissue allowing a faster gas exchange. Cuts break completely the protective layer of the fruit and expose the tissue directly to the environment. The secretion and production of anti-fungal substances diminishes as avocado ripens (Zamora, 1991; Morales, 2001). The damage is more notorious in fruits along the packaging process, mainly due to inadequate handling (dropping) that affects the number of fruits with export quality. The resistance to mechanical damage is given by the composition of the cells of the epidermis and the arrangement of the vascular tissue. A strong, elastic peel will not present any damage as a result of mishandling (Morales, 2001).

3. MATERIALS AND METHODS

3.1. Description of the Experimental Site

The experiment was conducted at Jimma University, College of Agriculture and Veterinary Medicine, in the postharvest management laboratory and the avocado fruits were obtained from Melkassa Agricultural Research Center (MARC), Ethiopia.

Table 1. Description of the Experimental Sites

Attributes	**Melkassa Agricultural Research Center, Ethiopia**	**Jimma University college of Agriculture and veterinary medicine, Ethiopia**
Location	-	356 km away from Addis Ababa
Elevation	1550 m.a.s.l.	1710 m.a.s.l
Latitude	of 824’ N	7^{o}33”N and 8°45´ N36.57^{0} E and 37°40´ E
Longitude	of 3921’ E	
Average annual rainfall in the area	768 mm, which is erratic (variable) and uneven in distribution	1500 m.m from April to the end of October
The mean maximum temperature	28.5 ^{0}C	26.8^{0}C
The mean minimum temperature	12.6 ^{0}C	11.4^{0}C
The mean maximum and minimum relative humidity	96.5% and 29.92% respectively	91.4% and 32.2% respectively
		* At the time of investigation the laboratory environment was at ambient conditions

Bureau of Planning and Economic Development of Oromia Regional state, Physical planning Development. Finfinne, Ethiopia (BPEDORS, 2000).

3.2. Experimental Materials and sample size

Avocado fruits were obtained from Melkassa Agricultural Research Center. The avocado cultivars used for this study was Ettinger, Fuerte, and Pinkerton. The fruit trees are eight-year old and fruits were selected according to canopy development and fruit load. Fruits from each of the three cultivars were handpicked at the same time. To minimize variation in size, appearance, maturity and absence of physical defects before harvesting, an adequate number of uniform fruits were labeled on six trees per each cultivar. Each sample consisted of 41 labeled. About 1107 avocado fruits were used for the experiment.

Table 2. General information about the avocado cultivars

Parameters	Cultivars		
	Ettinger	**Fuerte**	**Pinkerton**
Tree shape	Medium spreading	Large spreading	Medium spreading
Types of flowers	Type-B	Type-B	Type-A
Horticultural Maturity Indices (dry matter %)	19.8 %	19.0 %	21.6 %
Fruit size	10-12 oz	10-12 oz	14-16 oz
Fruit Color Before/after ripe	Green/ Green	Green/ Green	Green/ Green
Skin (peel) character and texture	Glossy smooth/ waxy	Medium-thin skin/smooth	Medium pebbly skin/ Rough pebbly
Moisture content (%)	80.4 %	81.9 %	72.1 %

Kuinimeri A. 2007

3.3. Experimental design and layout

The experiment consisted 3x3 factorial combination of three levels of fruit dropping heights (DH_1, DH_2 and DH_3) and three avocado varieties ($V_{1=}$ Ettinger, V_2 = Fuerte and $V_{3\ =}$ Pinkerton) arranged in a completely randomized design (CRD) with three replications. The three fruit dropping heights, (DH_1 = control, DH_2 = 0.79 m and DH_3 = 1.58 m), refer to the height from which the avocado fruits were dropped. Randomization was done separately and independently for each of the replications where the treatments were assigned completely at random as described by Gomez and Gomez (1984).

Factor A = Drop Heights of avocado fruits (DH_1, DH_2 and DH_3) with three levels

Where: DH_1 is 1.58 m, DH_2 is 0.79 m and DH_3 is control

Factor B = Cultivar of avocado fruits (V_1, V_2 and V_3) with three levels

Where: V_1 is Ettinger, V_2 is Fuerte and V_3 is Pinkerton

Table 3. Treatment combination for the experiment

Dropping heights	**Cultivar**	**Treatment combination**
	C_1	DH_1C_1
DH_1	C_2	DH_1C_2
	C_3	DH_1C_3
	C_1	DH_2C_1
DH_2	C_2	DH_2C_2
	C_3	DH_2C_3
	C_1	DH_3C_1
DH_3	C_2	DH_3C_2
	C_3	DH_3C_3

*

The statistical model that was used for the analysis of the data is:

$$Yij = \mu + ai + bj + (ab)ij + eij$$

Where Y_{ij} = is the observed value of Quality of avocado fruits

μ = the overall mean

a_i = fixed effect of i^{th} Dropping Height (DH1, DH2 and DH3)

b_j = fixed effect of j^{th} cultivar (C1, C2 and C3)

$(ab)_{ij}$ = interaction effect of dropping heights and cultivars

e_{ij}= random residual effect

3.4. Experimental Procedures

Matured green unripe fruits of Ettinger, Fuerte and Pinkerton avocado cultivars were obtained from Melkassa Agricultural Research Center(MARC). Fruits were hand picked at the early morning of the day. collected in to plastic boxes and transported to horticulture laboratory at Melkassa Agricultural Research Center(MARC). Sample initial weights were taken for each cultivar before packaging and transportation. Then packed in to pitted carton box. Cushions were used at the bottom of the carton and the fruits were arranged in a single layer, and transported from Adama to Addiss Abeba airport for 1:30-2 hours then transported by airplane to Jimma town for 5- 6 hoursand transported to JUCAVM post harvest management laboratory. Then the protective material was removed. Fruits were sorted and washed thoroughly by tap water. Then fruits were air dried for 10 minutes, and the selected concrete surface cleaned and sterilized with 3 per cent (3%) sodium hypo chlorate and with detergents. After it dries the clean surface were surrounded by 50x50cm carton box to control fruit bounce and contamination from unclean place and inside the box pure unused A4 paper was spread on the cleaned and cartoon surrounded surface to ensure that no contaminants come in contact with fruits while dropping to the concrete surface. Moreover, fruits were randomized to the treatment combinations shown in *Table 3*. Fruits were coded and labeled depending on the respective treatment combination. Then avocado fruits were dropped at the prescribed heights on to the smooth, cleaned sanitized and bounded concrete surface. The fruits treated on zero (control) height served as control. The treated fruits were transferred and kept inside cartons boxes and stored at room temperature in the Post harvest management laboratory. Each experimental unit consisted of 41 avocado fruits of which two avocado fruits were randomly removed for destructive measurements and additional 5 fruits were kept for non-destructive measurements. And the entire experiment was replicated three times. The Data recording was started on the dropping day for some parameters and continued at three days interval from treated and control samples until the overall acceptability became unsatisfactory for each lot of samples.

3.5. Data collected

Data on the following physical and chemical parameters were recorded starting from setup of the experiment until its termination.

3.5.1. Physiological Weight Loss (PWL %)

Individual avocado fruits were weighed using a balance (model of TWIII and made in USA). Physiological weight loss was calculated as a percentage of the difference between the initial weight and the final weight relative to the final weight. Percentage weight loss was calculated as follows:

$$PWL = \frac{Iwt - Fwt}{Iwt} X100 \qquad \text{........................ (Eq. 1)}$$

Where, PWL is physiological weight loss, Iwt is initial fruit weight and Fwt is final fruit weight

3.5.2. Pulp to peel ratio

To determine the pulp to peel ratio, first the fruits were peeled and the weights of the pulp and peel were taken separately on its wet basis. Then the weight of the pulp was dived to that of the peel (Vali *et al*, 2011).

3.5.3. Flesh Firmness (N)

Flesh firmness was determined objectively by a test by using a Texture Analyzer (TA-XT plus, UK) and TA-XT plus software following procedures described by Fan et al. (1999). Accordingly, the force required for the plunger to press into the fruit to a depth of 5 mm was recorded, and expressed in Newton. Firmness stable Microsystem with 2 mm plunger tip, with flat head stainless-steel cylindrical probe was used for the measurement of fruit firmness. The TA-XT plus was calibrated to 200 kg load of force and the plunger head was placed on the outer surface area of the equipment. Steady downward pressure was applied until the plunger has penetrated the flesh of the central part of the fruit up to the depth which is adjusted on the software on the plunger settings. The machine was set for compression at a speed of 1.5mm/sec. For the present research from each treatment two fruits were used from all treatments at a time and the average result was used for the analysis. The start of penetration test was the contact of the probe with the surface of avocado fruits and finished when the probe penetrated the tissues to a depth of 5 mm. The process was repeated six times on the other side of the same fruit after coding the first reading.

3.5.4. Peel color (*Chroma Value)*

Total colour change of samples were determined using CIE (Commission Internationale de L'Eclairage) L*a*b* color space to evaluate the effect of dropping on color change of samples using tri-stimulus colorimeter (Accu probe HH06, UK), which was calibrated using white tiles. The instrument was standardized with standard white tile (L=83.14, a*=-3.67 and b*=10.79). *Chroma* were expressed in terms of "L*" value (lightness, ranging from zero (black) to 100 (white), "a*" (redness) value and "b*" (yellowness) value. Color measurement was made on day zero and when data were collected at the specified day intervals. Fruit colors on day zero were considered a target sample color and color changes were evaluated as compared to day zero color. Six readings per fruit were taken from each sample by changing the position of the avocado fruits to get uniform color measurements (Maftoonazad and Ramaswamy, 2005). Quality assessments were done using the *Chroma* value as a determinant for colour change. *Chroma* was calculated using equation Eq. 2.

$C=\sqrt{a^2+b^2}$ …………………………………………………………………………… (Eq. 2)

3.5.5. Total soluble solid (^{0}Brix)

The total soluble solid (TSS) content of avocado fruit pulp was determined using a digital hand held refractometer (Bellingham + Stanley 45-2, UK). The percentage of TSS was obtained from direct reading of the refractometer in Degree Brix. First the refractometer was calibrated with distilled water, and after calibration, TSS of juice was determined. Homogenous sample was prepared by blending the avocado flesh in blender. The sample was thoroughly mixed and drops of juice were placed on the prism surface then prism lid was closed. The position at which the demarcation line between the light and dark regions crosses the vertical scale gives the percentage of soluble solids readings. Multiple measurements (3-5) were taken per a treatment and the average value was used. After each test, the prism plate was cleaned with distilled water and wiped with a soft tissue.

3.5.6. Titratable acidity (TA %)

Titratable Acidity (TA) was determined by titration according to procedures described by Association of Analytical Chemists AOAC (2000) official method 981.12. Fruits were crushed and made into juice, and 5 ml of sample from the pulp was taken and added in to 250 ml conical flask. Then 10 ml distilled water was added to make the fruit color light to facilitate clear end point. To determine the total titratable acidity of the pulp, fresh 0.1N NaOH was used. Percentage of titratable acidity was calculated using the following formula:

$$TA = \frac{V_1 X\ N X\ E}{V_2} X100 \quad \text{(Eq. 3)}$$

Where, V1 = Volume of NaOH used

N = Normality of NaOH

E = Equivalent weight of acid,

V2 = Volume of sample taken for estimation

A laboratory burette of 25ml or 50ml capacity, A 10ml pipette, beaker (250ml), a filter (muslin cloth or fine filter), an extractor or homogenizer, A bottle of distilled water, Sodium Hydroxide (NaOH) (The Standard Laboratory solution of 0.1N which was used in the actual titration was considered to be dilute, and can readily be purchased in this form) and Phenolphthalein was used. Three drops of phenolphthalein were added to the juice solution in each beaker from a dropping pipette which was specifically kept for that purpose. After ensuring the tap on the burette was shut and using a funnel pour (cause to flow) the 0.1N solution of NaOH into the burette until it reaches the zero mark. Slowly the sample was titrated with the NaOH into the juice solution (with a 25ml burette). Using phenolphthalein as an indicator, the point of neutrality was reached when the indicator changed from colorless to pink (A.O.A.C., 2000).

3.5.7. pH (%)

The pH of the sampled avocado fruits was determined following the method described in Rangana (1979). Ten gram of avocado fruit flesh was homogenized and made into juice. Then the pH meter was standardized with pH 4.0, 7.0 and 10 buffer solutions. After standardization, the pH of each juice sample was measured by using a digital pH meter (CP-505, Poland)

3.5.8. Dry matter (%)

The avocado fruits were sliced into 2 mm thick pieces and allowed to air dry and placed in an oven (model M200CF and made in England) at 60°C for two days. Weight of the slice was measured before and after drying. After equilibrium of weight dry matter percentage (DM %) was calculated using Equation (4) (A.O.A.C. 1995).

$$\text{Dry Matter \%} = \frac{\text{Final Dry Weight (g)}}{\text{Initial Wet Weight (g)}} \times 100 \qquad \text{(Eq. 4)}$$

3.5.9. Crude fat content determination (%)

Crude fat content was determined by Soxohlet fat extraction according to A.O.A.C (2000) official method 2003.06. A clean and dried thimble containing about 2 g of dried sample and covered with fat free cotton at the bottom and top were placed in the extraction chamber. The beaker was rinsed several times with the solvent hexane. The sample contained in the thimble was extracted with the solvent hexane in a Soxhlet extraction apparatus (SZC-C fat determinate, China) for 6-8 hrs at a condensation rate of at least 3-6 drops per second.

Weight of fat $(W_f) = W_a - W_b$; *where,* W_a *= weight of extraction flask after extraction;*

W_b *= weight of extraction flask before extraction*

$$\text{Crude fat content (\%)} = \frac{Wf}{SW} \times 100 \qquad \text{(Eq. 5)}$$

Where, SW = weight of samples

3.5..10. Decay or Rotting (%)

The decay or rotting of the stored avocado fruits were determined by their visual observations by using *(Eq. 6).*

$$\text{Decay (\%)} = \frac{\text{number of decayed fruit}}{\text{Initial number of all fruits}} \times 100 \qquad \text{(Eq. 6)}$$

3.5.11. External bruise area (mm)

The external bruise area of the avocado fruits was calculated by measuring the length of bruise area then computing impact damage classification according to (Vurasvus and Ozguven, 2004) average bruise diameter classification (graded).

3.5.12. Time to ripening (days)

The ripening time were measured by counting the time starting from at the beginning of the harvest to the day at which the fruit become edible.

3.5.13. Storage Life (days)

The shelf life of avocado fruits was calculated by counting the days required for them to attain the last stage of ripening, but up to the stage when they remained still acceptable for commercial marketing (About 10% physiological loss in weight is considered as an index of termination of the shelf life (threshold level) of fruit commodities (Pal *et al*., 1997; Acedo, 1997).

3.6. Data analysis

The data were analyzed using SAS (SAS Institute Inc., 2010) version 9.2. When ANOVA shows significant difference ($P < 0.05$), mean separation was carried out by LSD. Decay percentage data were transformed by square root transformation to fulfill ANOVA assumptions.

4. RESULTS AND DISCUSSION

4.1. Physiological weight loss (PWL %)

Physiological weight loss (PWL) of the avocado fruits was recorded, at 3 day intervals, from the beginning of the storage experiment throughout the storage time, at ambient conditions. . Physiological weight loss appeared to be the major detrimental factor of storage life and quality of the stored avocado fruits. In the current study the interaction between dropping height and cultivars resulted in a significant ($P < 0.05$) difference in PWL of the avocado fruits (*Table 4*). Physiological weight loss of avocado fruits that were not dropped from any height (control) was significantly lower than those fruits that were dropped from a relatively higher height above the ground. Those avocado fruits dropped from a height of 0.79 m and 1.58 m above the ground had substantial weight loss throughout the storage period. The highest value for PWL of avocado fruits was recorded in fruit cultivars Ettinger and Fuerte dropped from a height of 0.79 m and 1.58 m above the ground. Whereas, the lowest value for physiological weight loss was recorded in fruits of the cultivar Pinkerton dropped at a height of 0, 0.79 and 1.58 m above the ground (*Table 4*).

The lower PWL value recorded in avocado fruits of Pinkerton cultivar compared to that of Ettinger and Fuerte could be due to varietal differences in the protective layer (rough pebbly peel) of the fruits that might have resulted in differences to mechanical damage. With an increase in dropping height from the ground, there was a significant increase in PWL of the avocado fruits, which also varied among the varieties.

The result of present study is in accordance with that of Morales (2001) the resistance to mechanical damage is given by the composition of the cells of the epidermis and the arrangement of the vascular tissue. A strong, elastic peel will not present any damage as a result of mishandling.

Table 4. Effect of fruit dropping height on physiological weight loss of selected avocado cultivars throughout experimental period

Fruit Dropping height (m)	Cultivar	Number of days after storage					
		3	6	9	12	15	18
Control		3.3^{h}	18.7^{h}	47.0^{i}	50.9^{i}	52.3^{h}	54.7^{i}
0.79	Pinkerton	3.6^{h}	19.0^{h}	52.3^{h}	54.7^{h}	56.1^{g}	58.7^{h}
1.58		4.6^{g}	20.5^{g}	54.2^{g}	56.2^{g}	58.2^{f}	61.2^{g}
Control		10.9^{f}	51.5^{f}	54.7^{f}	57.1^{f}	59.5^{e}	64.3^{f}
0.79	Fuerte	11.6^{e}	53.6^{d}	56.6^{d}	58.2^{e}	62.8^{c}	65.8^{d}
1.58		12.6^{d}	55.3^{b}	58.1^{b}	60.0^{c}	64.8^{b}	68.8^{b}
Control		13.6^{c}	52.6^{e}	56.1^{e}	59.0^{d}	60.6^{d}	64.8^{e}
0.79	Ettinger	14.5^{b}	54.4^{c}	57.1^{c}	60.5^{b}	62.8^{c}	67.4^{c}
1.58		15.5^{a}	56.3^{a}	61.4^{a}	62.4^{a}	69.7^{a}	71.7^{a}
LSD (5%)		0.76	0.48	0.03	0.09	0.19	0.26
CV (%)		4.44	0.66	0.04	0.08	0.18	0.23

Means with the same letter (s) within a column are not significantly different

Similarly Zamora *et al.* (1991) and Morales (2001) reported that mechanical damage accelerates water loss and disrupts the superficial arrangement of the tissue allowing a faster gas exchange. Cuts break completely the protective layer of the fruit and expose the tissue directly to the environment.

Additionally Kader (2004) reported that mechanical injuries (such as bruising, surface abrasions and cuts) can accelerate loss of water that could result in PWL. Ferris *et al*. (1993; 1995) and Lladó and Dominguez (1998) also observed that mechanical injuries increased weight loss in banana fruits. Since the fruits are harvested and stored until they are consumed, they continuously undergo a loss in weight, which is largely loss of water from the fruits

Damaged fruits could have higher rates of respiration that could lead to weight loss as a result of carbohydrate breakdown and water loss. According to FAO (2003) manipulating the environment around any produce (damaged and undamaged) and can modify the concentration of gases in the produce. Packing, through its effect of reducing respiration rate, reducing ethylene concentration and action, delaying ripening and senescence, increases product's shelf life.

Generally, the findings in the current study showed that dropping of avocado fruits from a specific height above the ground can result in mechanical damage that leads to increased PWL with an increase in height. Genotypic differences in PWL among fruits of the different avocado varieties indicate that some varieties like Pinkerton are more resistant to mechanical damage than Fuerte and Ettinger, in that order. Hence during handling of avocado fruits, specific requirements of a specific variety should be well understood and implemented accordingly. Among the three varieties, avocado fruits of the Ettinger variety are highly susceptible to mechanical damage as compared with Pinkerton and Fuerte.

4.2. Pulp to peel ratio

Both dropping height and varietal differences were causes for the observed differences in pulp to peel ratio of the avocado fruits throughout the storage period (Figure 1). However, impact damage has shown an effect on the pulp to peel ratio of the fruits at the last day of storage by epidermal flesh adhesion on Ettinger 0.79 and 1.58 m and Fuerte 1.58 drop height treated avocado fruit cultivars by increasing the weight of the peel and decreasing the ratio after the fruit is ripe. But flesh adherence not occurs on Pinkerton avocado fruit cultivars treated on (0.79 and 1.58 m drop heights) as well as Fuerte treated on 0.79 m drop heights. This result was in accordance with Morales (2001) that reported the resistance to mechanical damage is given by the composition of the cells of the epidermis and the arrangement of the vascular tissue. A strong, elastic peel will not present any damage as a result of mishandling. Similarly, Everett *et al.* (2007) reported that surface of avocado fruit showing a lenticels pore with part of the cuticle layer the epidermis and one or more cell layers below frequently showed no apparent damage, whilst a single area of these cells did show browning, internal disruption, and some cell wall damage. More extensive browning and discernible (visible) cellular collapse were visible in the region of the lenticels which were the fruit damaged (Everett *et al.* (2007).

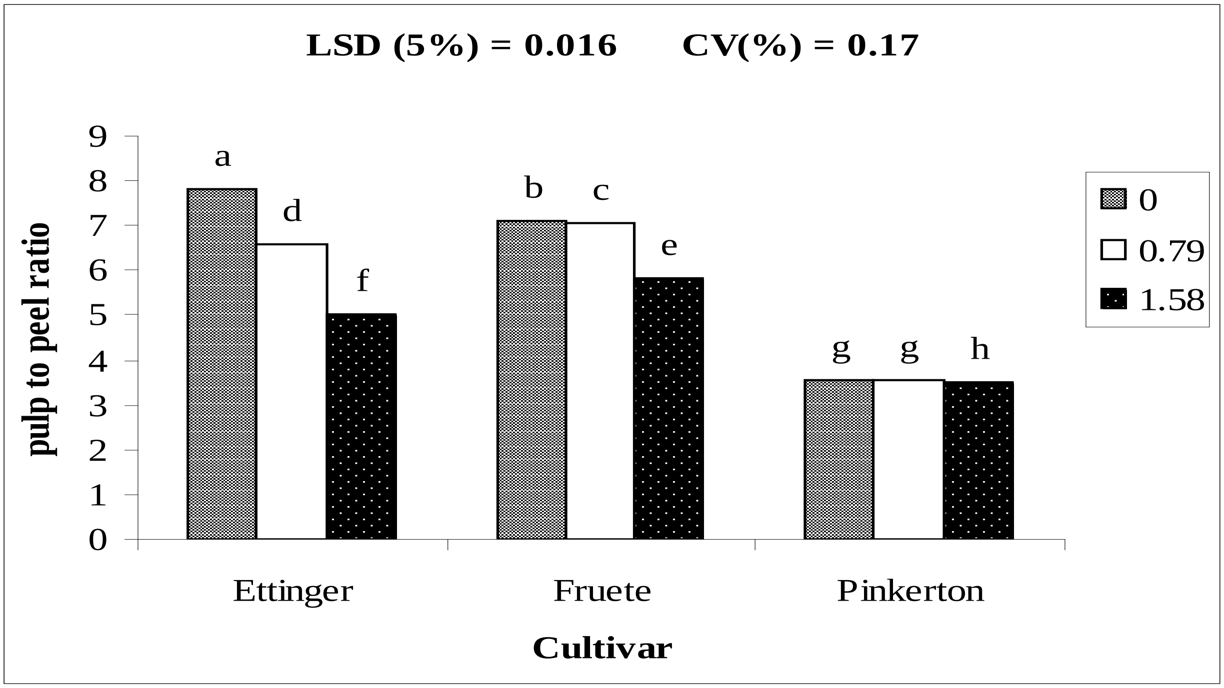

Figure 1. *Effect of drop height on the Pulp: Peel ratio of selected varieties on the last day*

4.3. Fruit Firmness (N)

Fruit firmness is a major attribute that dictates the postharvest life and quality of fruits. It is an important factor indicating the internal freshness of avocado fruits and influences consumer acceptability of fresh fruits. Means recorded for avocado fruit firmness are presented in Table 5. Both fruit dropping height and cultivar showed a significant ($P < 0.01$) interaction effect on the firmness of the fruits. Throughout the experimental period, fruit firmness was as high as 2398.2 kgf in avocado fruits from the Pinkerton (control) cultivar, after 3 days of storage, and 38.5 kgf in Ettinger fruits dropped from a height of 1.58 m and stored for 18 days. Similarly, after 15 days of storage the maximum fruit firmness value was recorded in fruits of cultivar Pinkerton (control).

the of observation was Pinkerton cultivar at the control (565.6 kgf), Pinkerton cultivar on drop height 0.79m (535.9 kgf), and Pinkerton cultivar on drop height 1.58m (533.7 kgf) followed by Fuerte cultivar on the control (297.7 kgf), Fuerte cultivar on drop height 0.79m (218.3 kgf), Fuerte cultivar on drop height 1.58m (206.7 kgf) and Ettinger cultivar on the control (185.8kgf), Ettinger cultivar on drop height 0.79m (158.7 kgf) Ettinger cultivar on drop height 1.58m (118.6 kgf) (*Table5*). All treated Ettinger and Fuerte cultivar were exhibited comparatively softer(acceptable to eat) as compared to that of the cultivar pinkerton treated fruits at the day of observation that were Pinkerton cultivar on the control (565.6 kgf), Pinkerton cultivar on drop height 0.79m (535.9 kgf) and Pinkerton cultivar on drop height 1.58m (533.7 kgf) (*Table 5*). However, on the 18th day of observation all avocado cultivars and dropping height become non significant. Whereas Pinkerton at the control treatment gave higher firmness value were differ from other treatments (274.8 kgf) on the day of storage.

As shown in Table 5, undamaged fruit were firmer than the damaged ones. This result was in accordance with different research findings (Arpaia *et al.,* 1987; Brummell, and Harpster 2001) that reported mechanical damage of fruits had effects on firmness throughout storage period of avocado fruits also

Similarly Kashmire and Kader (1978) reported that during ripening of fruits and for that matter avocado, they tend to soften either as result of the cells losing water and becoming less turgid or by the breakdown of the cell wall components as a result of physical damage.

Additionally, according to Fischer and Bennett (1991) the damaged treatment had a significant effect on fruit softening which could be a result of the fruit increasing in metabolic rate and therefore losing water, making the cells flaccid (loose) and collapsing upon pressure. Additionally fruit softening is closely connected with cell wall modifications caused by some cell wall degrading enzymes (Fischer and Bennett, 1991).

Table 5. ***Effect of drop height and cultivar on the response of firmness throughout the storage time***

Dropping height (m)	Cultivar	Number of days after storage					
		3	6	9	12	15	18
Control		2398.2[a]	2190.5[a]	1935.2[a]	1408.5[a]	565.6[a]	274.8[a]
0.79	Pinkerton	2390.3[b]	2167.5[b]	1889.2[b]	1330.6[b]	535.9[b]	114.8[b]
1.58		2373.3[c]	2107.4[c]	1739.0[c]	1267.5[c]	533.7[b]	90.6[b]
Control		2189.0[d]	1790.2[d]	820.3[d]	588.2[d]	297.7[c]	89.2[b]
0.79	Fuerte	2174.2[e]	1717.8[e]	765.0[e]	467.5[e]	218.3[d]	88.2[b]
1.58		2156.1[f]	1623.3[f]	719.0[f]	372.0[f]	206.7[e]	67.2[b]
Control		2132.9[g]	1026.9[g]	647.0[g]	241.0[g]	185.8[f]	66.5[b]
0.79	Ettinger	2131.1[g]	1007.3[h]	631.5[h]	228.8[gh]	158.7[g]	53.6[b]
1.58		2120..9[h]	992.9[i]	531.9[i]	212.1[h]	118.6[h]	38.5[b]
LSD (5%)		6.90	7.09	11.24	21.62	9.75	6.79
CV (%)		0.18	0.25	0.61	1.85	1.81	1.14

Means with the same letter (s) within a column are not significantly different.

4.4. Peel color (Chroma Value)

Color is a very important determinant of quality and consumer acceptability. It is most important characteristic to assess ripeness and postharvest life of avocado fruits and has major importance in making purchasing decision. Dropping Avocado fruits significantly accelerated the change in fruit discoloration (*Figure 2*). Different cultivars showed significant differences in discoloration of the stored fruits in response to damage. Interaction effects of dropping heights and cultivars were also observed. Most often, Avocado fruits are consumed at their maximum organoleptic quality which is attained when the fruit had the full green/yellow stage before discoloration. The discoloration of avocado could be observed as a result of variation in fruit brightness can be considered as an indicator of color browning in fruits (Avila and Silva 1999; Dadalt *et al*. 2007).

The total color difference (*Chroma* values) extensively used to characterize variations in color perception as shown in *Figure 25*. *Chroma* values summarize the progressive deviation between the original colors, as found at first measurement on the first day followed by subsequent measurements.

The *Chroma* value in drop treated Avocado fruits was decreased and they become darker within 12-15 days of storage compared to those fruits which were controlled (18-43 days) depending on the cultivars. Generally the highest rate of color change was observed in Avocado fruits treated higher dropping height (1.58 m) followed by 0.79 m and the control. As shown in the Figure 5, damaged fruits were darker than the undamaged ones. This result was in accordance with Everett *et al.* (2007) that reported more extensive browning was visible in the region of the lenticels which were the fruit damaged. Also they reported that microscope observations showed patchy areas of browning in the flesh, and much of the browning appeared to be the result of diffuse pigmentation. During the course of ripening, chloroplasts in the peel are transformed into chromoplasts containing red and yellow pigments (Lizada, 1993). In this study, fruits dropped from lower heights were effective in preserving the green/yellow color. The color of the controlled avocado fruits was also much glossier and brighter than fruits that were dropped from the higher dropping height.. Additionally Palou *et al*. (1999) and Weemaes *et al*. (1999) reported that some variations in *Chroma* values might be due to change in chlorophyll contents of individual fruit as it was a result of degradation of chlorophyll and carotenoid pigments.

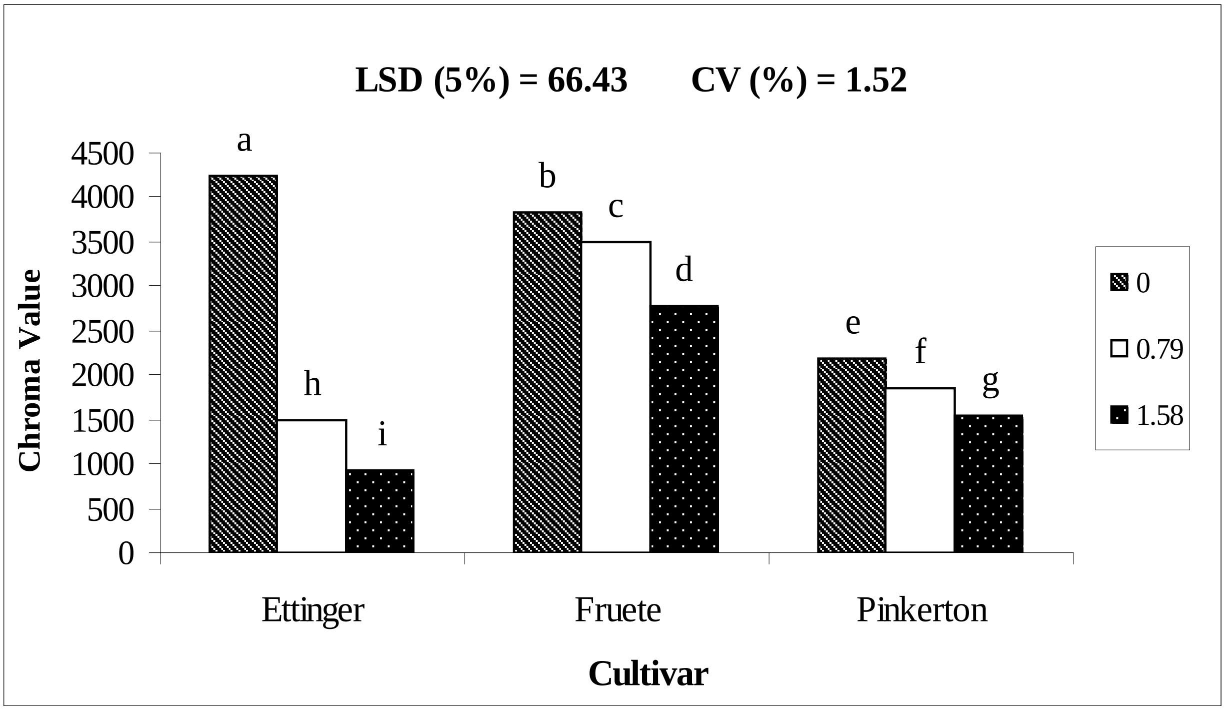

Figure 2. Effect of dropping height on the Chroma of three different avocado Cultivars

4.5. Total soluble solid (TSS)

Total soluble solids are important factor to be considered with respect to consumer acceptance. It is expected to increase during ripening and decrease towards senescence (Tasdelen and Bayindirli, 1998). In the present study we observed a significant ($P < 0.01$) interaction effect between dropping heights and cultivars on the TSS content of the Avocado fruits (*Table 6*). The total soluble solids contents of drop height treated fruits were not significantly different ($p<0.01$) but there was a significant difference between the three avocado fruit cultivars namely Ettinger, Fuerte and Pinkerton until the ninth day of storage periods. The TSS values for all drop height and control and cultivars were within the range 1.2-2.3 (^{o}Brix) before ripening. Total soluble solids increased as ripening progressed. However, there was a significant difference on the three drop heights treated fruits and between the three cultivars starting from the ninth days to throughout the storage periods. At the 12th day of storage Ettinger avocado fruits dropped from 1.58 and 0.79 m height had the lowest value recorded 6.6 and 7.10, respectively. In the avocado cultivar Ettinger, fruits that were not dropped (control) from any height had 10.7°Brix on the 1st day of the experiment.

However, at the 18th day of storage Fuerte cultivar dropped from a height of 1.58 showed the minimum Brix value when compared to those fruits dropped from a height of 0.79 m and the control (10.3°Brix). But, there was no significant effect on pinkerton cultivar treated on the three of drop height (control, 0.79 m and 1.58 m) which was (10.8 ^{0}brix) during the last day of storage. The result of present study is in accordance with that of Biale and Young (1969) Sugar content (total carbohydrates) in avocados is very variable. For instance, concentration of sugar decreases rapidly during storage and ripening. Thus, sugar content may vary depending on growth conditions, the exact picking time and the length and condition of storage before the analysis is carried out. According to Sanches *et al*. (2008), the reduction of soluble solids can be explained by the use of these elements as a source of energy. In similar results total soluble solids also decreased for 'Montenegrina' tangerines, whereas for 'Rainha' lime fruits there was no significant response (Cândida Raquel Scherrer Montero *et al.*, 2009). Mechanical damage has its own effect on the rate of respiration process. Sugars play an important role in the respiration of the avocado during the ripening process. This result is in accordance of Liu *et al*. (1999) that during avocado growth, carbohydrates are stored; however, once the fruit is harvested these carbohydrates are consumed for postharvest physiological processes such as respiration via enzymatic mechanisms that metabolize the C7 sugars. This suggests that the C7 sugars play an important role in the respiration of the avocado during the ripening process.

Table 6. Effect of dropping height and cultivar on the response of avocado TSS on the last day of storage

Dropping height (m)	Cultivar	Number of days after storage					
		3	6	9	12	15	18
Control	Pinkerton	1.40[b]	4.27[b]	10.20[d]	10.80[a]	10.80[a]	10.80[a]
0.79		1.37[b]	4.30[b]	10.27[cd]	10.70[b]	10.80[a]	10.80[a]
1.58		1.37[b]	4.33[b]	10.30[c]	10.20[e]	10.60[a]	10.80[a]
Control	Fuerte	1.30[c]	2.27[c]	9.90[g]	10.67[bc]	9.60[b]	9.13[b]
0.79		1.30[c]	2.30[c]	10.00[f]	10.60[c]	9.10[b]	8.47[b]
1.58		1.20[d]	2.30[c]	10.10[e]	10.30[d]	9.60[b]	8.20[b]
Control	Ettinger	2.30[a]	5.17[a]	10.43[b]	10.73[ab]	9.00[b]	7.10[c]
0.79		2.30[a]	5.20[a]	10.43[b]	7.10[f]	7.04[c]	6.90[c]
1.58		2.30[a]	5.23[a]	10.57[a]	6.60[g]	6.01[c]	6.00[c]
$LSD_{(5\%)}$		0.05	0.07	0.09	0.09	0.84	0.93
CV(%)		1.65	1.10	0.50	0.52	5.26	6.22

Means with the same letter (s) in a column are not significantly different.

4.6. Titratable acidity (%)

The acidity of Avocado plays the major role and imparts taste to the fruit. Titratable acidity (TA) is an important consumer variable as the balance of TSS and TA relates to overall taste and consumer acceptability. TA is directly related to the concentration of organic acids present in fruits. The TA values of dropping heights decreased with storage time (*Figure 3*) and the value was significantly higher ($P \leq 0.01$) in Pinkerton and Fuerte cultivars treated fruits compared to the Ettinger cultivars.

There was significant ($p<0.01$) difference among cultivars and drop heights in terms of percent titratable acidity. The TA of cultivar starts to decline starting from the 12th day of storage life to the final storage time. On the 12th day of storage the TA declined in Ettinger fruits that were dropped from 1.58 and 0.79 m (0.014%) but in the control it was (0.020%). However at 18th days of storage Ettinger at the control were (0.027%) and Fuerte cultivar at drop height 0.79m and 1.58m were (0.025%), and Fuerte cultivar at the control (0.027) and

Pinkerton cultivar drop height 1.58 m (0.027%), Pinkerton cultivar drop height 0.79m and control (0.028%). The lowest titratable acidy between treatments were observed (0.023%) from Ettinger 0.79 and 1.58 m and (0.020%) from Ettinger drop height 1.58m and (0.025%) from Fuerte drop height 0.79m and 1.58m were recorded respectively whereas Fuerte cultivar at the control (0.027%) and Pinkerton cultivars at the control and 0.79m drop height showed that the higher (0.028) TA value on day of storage (*Figure 3*). The result of present study is in accordance with that of (Pisarczyk, 1982; Salveit and Locy, 1982; Mao *et al*., 1995) that Plant organs submitted to vibration or mechanical damage usually increase their respiration rates in comparison to uninjured controls. Therefore, the impact treatments tested here could be accelerating the oxidation of acids by the enhancing respiration.

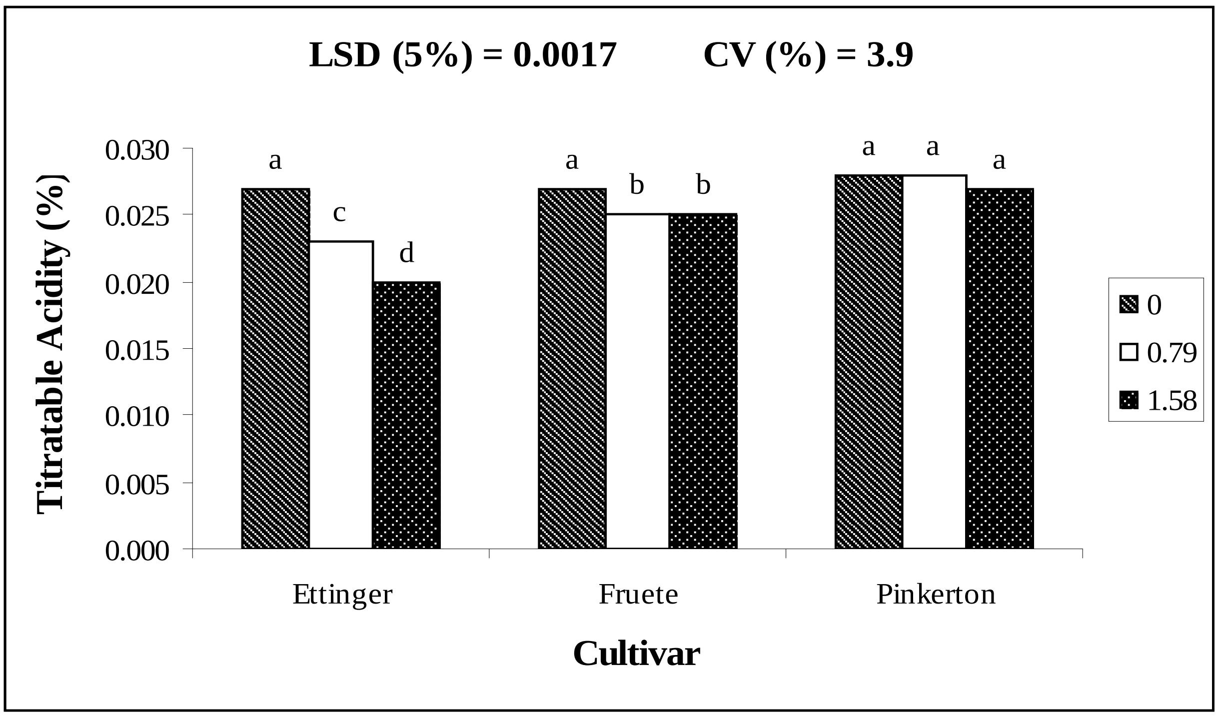

Figure 3. Effect of drop height on percentage TA of selected avocado fruits cultivars

4.7. pH (%)

Avocado pH lies in the range of 6 to 6.5 (Soliva-Fortuny *et al*., 2004). There was significant variation ($p<0.01$) among treatments in terms of pH. The pH of the treated fruits ranged from

4.84 – 6.51 whereas the control treatment gave higher pH value (6.51) on 18th days of storage. The maximum pH value among the treated fruits observed on the 18th day of storage was Pinkerton cultivar at the control (6.51), Pinkerton cultivar on drop height 0.79m (6.48), and Pinkerton cultivar on drop height 1.58m (6.47) followed by Fuerte cultivar at the control (6.24), Fuerte cultivar on drop height 0.79m (6.14), and Fuerte cultivar on drop height 1.58m, Ettinger cultivar drop height 0.79m and Ettinger cultivar at the control shows the value (5.81) Ettinger cultivar on drop height 1.58m were the least (4.84) at the day of investigation (Table 7). All these treatments exhibited comparatively lower pH as compared to that of the fruits at the first day of observation that Pinkerton cultivar at the control (7.07), Fuerte cultivar at the control (6.75) and Ettinger cultivar at the control (6.66)

The lower pH value recorded in treated fruits compared to control could be due to the differences in the disease control mechanism created by the internal composition of the fruit and different types of impact damage response. This result is in accordance with that of St. Leger *et al*. (2003) findings pectolytic (PL) was detected only when the pH reached 5.8. *C. gloeosporioides* did not colonize avocado fruits when the pericarp pH was lower than 5.8 and hypothesized ambient pH affects pathogenicity by altering the expression of cuticle-degrading enzymes and hydrophobin in the insect pathogen *Metarhizium anisopliae*.

These results indicate that avocado susceptibility is regulated by more than one mechanism: a decrease in the level of antifungal compounds and an increase in pH which modulates pectolytic (PL) secretion. Component in this complex process can be attributed to the physiological and biochemical changes that occur in the host during ripening and senescence and that lead to decreased host response and increased susceptibility.

Fluctuations of pH might be due to the variations in titratable acidity and the decline of acidity is attributed to increased activity of metabolism during ripening or due to their conversion into sugars and further utilization in metabolic process during storage (Rathore *et al*., 2007). During storage the fruit itself might utilize the acids so that the acid in the fruits during storage periods decrease.

*Table 7***.** Effect of drop height and cultivar on the response of avocado pH during storage of 18 days

Dropping height (m)	Cultivars	Number of days after storage					
		3	6	9	12	15	18
control		7.07[a]	6.90[a]	6.78[a]	6.78[a]	6.55[a]	6.51[a]
0.79	Pinkerton	6.77[b]	6.85[ab]	6.72[b]	6.72[b]	6.55[a]	6.48[a]
1.58		6.77[b]	6.77[bc]	6.64[c]	6.61[c]	6.55[ab]	6.47[a]
control		6.75[c]	6.75[cd]	6.62[c]	6.61[c]	6.54[ab]	6.24[b]
0.79	Fuerte	6.72[d]	6.67[de]	6.56[d]	6.54[d]	6.53[bc]	6.14[c]
1.58		6.70[e]	6.66[e]	6.52[e]	6.52[de]	6.51[c]	5.81[d]
control		6.66[f]	6.66[e]	6.50[e]	6.50[e]	6.47[d]	5.81[d]
0.79	Ettinger	6.66[f]	6.65[e]	6.49[f]	6.46[f]	6.42[f]	5.81[d]
1.58		6.64[g]	6.62[e]	6.24[g]	5.99[g]	5.96[f]	4.84[e]
LSD (5%)		0.09	0.08	0.03	0.03	0.01	0.07
CV (%)		0.08	0.70	0.29	0.28	0.12	0.70

Means with the same letter(s) within a column are not significantly different.

4.8. Dry matter (%)

No significant effect of drop height treatment on dry matter of avocado fruits was observed compared to the controls for all sampling dates. However there was significant effect attributable to avocado cultivars. The dry matter observed throughout the storage time on the three cultivars was Ettinger cultivar (22.83%), Fuerte cultivar (22.80%), and Pinkerton cultivar (21.80%). Dry matter content of most of avocado cultivars recorded from this ranges depending on the cultivar. According to California maturity standard that reported the standards adopted are the Californian minimum dry matter of 20.8% for ‘Hass’ or a slightly higher minimum dry matter content of approximately 25% to decrease disorders during storage (*Table 8*). (Gamble *et al*., 2010) No distinct correlation could be drawn between the effect of drop height during handling and cultivar on the percentage dry matter of avocados fruits during storage.

Table 8. Effect of cultivar on the dry matter of selected avocado fruits

Cultivar	Number of days after storage		
	3	9	18
Ettinger	22.8[a]	22.8[a]	22.8[a]
Fuerte	22.8[a]	22.8[a]	22.8[a]
Pinkerton	21.8[b]	21.8[b]	21.8[b]
LSD (5%)	0.01	0.01	0.01
CV (%)	0.09	0.09	0.09

Means with the same letter are not significantly different

4.9. Crude fat content (%)

Significant difference was observed with regard to crude fat content of avocado fruits compared to each other at the determination times. In the present work Ettinger and Fuerte avocado cultivar at 0.79 and 1.58m drop height treated fruits accumulated the maximum crude fat content throughout the storage period when compared to Pinkerton cultivars at the control, 0.79 and 1.58m. At day 15 Ettinger cultivar drop height 1.58m were recorded (20.09%), Ettinger cultivar drop height 0.79m (19.42%), Ettinger cultivar at the control (19.83%), Fuerte cultivar at drop height of 1.58m (19.10%), 0.79m (18.94%) and the control (18.50%). However, the minimum crude fat content were recorded from Pinkerton cultivars at the control (15.00%), Pinkerton cultivars drop height 0.79 (15.47%) and 1.58m (15.64%) (*Table 9*).

These results are in accordance with Mason (1981) that reported the oil content of avocado pear varies from species to species. The cultivar and the response to damage were different depending on the fruit internal cell composition and cell rupture. This result is related to Dolendo *et al*. (1966) who reported that during softening a decrease in degree of esterification (any of a class of often fragrant organic compounds that can be represented by the formula RCOOR1/2 and that are usually formed by the reaction between an acid and an alcohol with elimination of water) of pectin (any of various water-soluble substances that bind adjacent cell walls in plant tissues and yield a gel which is the basis of fruit jellies) in avocado fruit loosens the cells from each other and at that stage cells may be more easily ruptured, resulting in release of the lipids.

Similarly the lipid content and composition of avocados is affected by many factors such as fruit race, fruit position on the tree (Hatton *et al*., 1957) site within the fruit (Schroeder, 1987), maturity (Davenport and Ellis, 1959; Mazliak, 1965a; Kikuta and Erickson, 1968; Vakis *et al*., 1985; Eaks, 1990; Inoue and Tateishi, 1995), cultural practices (irrigation) (Lahav and Kalmar, 1977; Kruger and Claassens, 1996a), environmental conditions (rainfall, temperature) (Kaiser and Wolstenholme, 1994; Kruger and Claassens, 1996b; Mc Onie and Wolstenholme, 1982) and post harvest handling (Mazliak, 1965b).

It seems probable that these changes were due to the initiation of reserve lipid formation in the mesocarp of the fruit, while in damage susceptible fruits the bulk of fatty acids had arisen from phospholipids and glycolipids which were uniquely associated with these lipids.

There were changes in lipid content during the ripening and storage period. These were slight increases in the total lipids during storage of Ettinger and Fuerte cultivar drop treated fruits. These results are in accordance with Erickson and Kikuta (1965) that reported marked increases in monoglyceride and free fatty acid fractions, those lipids were involved to some extent in metabolic changes during the ripening process.

Crude fat content increments in present study also were due to the direct contact of oxygen to the damaged fruit tissue. These results are feet to Erickson and Kikuta (1968) suggestions that reported oxygen is definitely required for oleic acid (a monounsaturated fatty acid ($C_{18}H_{34}O_2$) obtained from natural fats and oils) synthesis in avocado fruit during storage.

*Table 9***.** Effect of dropping height on the crude fat content of selected avocado cultivars though out storage time

Dropping height (m)	Cultivar	Number of days after storage					
		3	6	9	12	15	18
control	Pinkerton	15.00^{h}	15.00^{i}	15.00^{h}	15.00^{i}	15.00^{i}	15.01^{i}
0.79		15.01^{h}	15.12^{h}	15.33^{g}	15.37^{h}	15.47^{h}	15.51^{h}
1.58		15.07^{g}	15.23^{g}	15.36^{g}	15.50^{g}	15.64^{g}	15.83^{g}
control	Fuerte	18.50^{f}	18.50^{f}	18.50^{f}	18.50^{f}	18.50^{f}	18.50^{f}
0.79		18.53^{e}	18.69^{e}	18.73^{e}	18.89^{e}	18.94^{e}	19.12^{e}
1.58		18.78^{d}	18.89^{d}	18.93^{d}	18.98^{d}	19.10^{d}	19.27^{d}
control	Ettinger	19.80^{c}	19.80^{c}	19.80^{c}	19.80^{c}	19.83^{c}	19.83^{c}
0.79		19.81^{b}	19.90^{b}	19.19^{b}	19.34^{b}	19.42^{b}	20.22^{a}
1.58		19.83^{a}	19.93^{a}	19.94^{a}	19.94^{a}	20.09^{a}	19.98^{b}
LSD (5%)		0.01	0.03	0.02	0.11	0.07	0.33
CV (%)		0.05	0.16	0.08	0.03	0.01	1.49

Means with the same letter(s) in a column are not significantly different.

4.10. Decay or rotting (%)

The decay or rotting percentages of treated fruits were significantly different ($p<0.05$) which treated by drop heights in three cultivars namely Ettinger, Fuerte and Pinkerton avocado fruits throughout storage periods. The disease incidence on avocado fruits increased with the passage of time at almost all drop treated (0.79 and 1.58m) Ettinger and Fuerte avocado cultivars. Ettinger avocado fruit cultivars drop height 1.58m and 0.79m shows a disease symptom after 14 days of storage, and all of the control fruits showed the symptom after 18^{th} day of storage. Different type of drop heights (control, 0.79m and 1.58m) with different avocado cultivars not only allow the occurrence of disease symptom but also deteriorate the freshness of the fruits during first two weeks of storage and later on showed few symptoms. All drop heights used for this experiment showed significant ($p<0.05$) effects on disease incidence of avocado fruits on the 15^{th}, 21^{th} and 33^{th} days of storage (*Figure 4*). Based on regular observation, the maximum average disease incidence (100%) was observed on

Ettinger cultivar drop height 1.58m treatments on the 15th day of assessment with the entire samples of fruits showing the symptom. On the other hand, the minimum disease incidence in the 15th day of storage (0%) was observed for Fuerte control and 0.79m drop height treated avocado fruits. Even after 30 days of storage, Pinkerton cultivars at the control showed the null anthracnose incidence compared with the other treatments.

During mechanical damage pathogens allowed to inter to the fruit and the susceptibility were increase due to the fungal attack. This result is in accordance with Yakoby *et al. (*2000, 2001) who reported that activation of quiescent fungal infections consists of processes that compromise host defenses directly or indirectly by detoxification of antifungal agents.
Similarly, the mechanical damage to the skin caused by bruising can serve as an entry point for postharvest rots (Everett, 2001) and in most fruit the wound site serves as a decay promoting source (Kays and Paull, 2004) Of the three different dropping heights in different cultivars against the pathogen *C. gloeosporioides* revealed significant suppression effect compared to control.

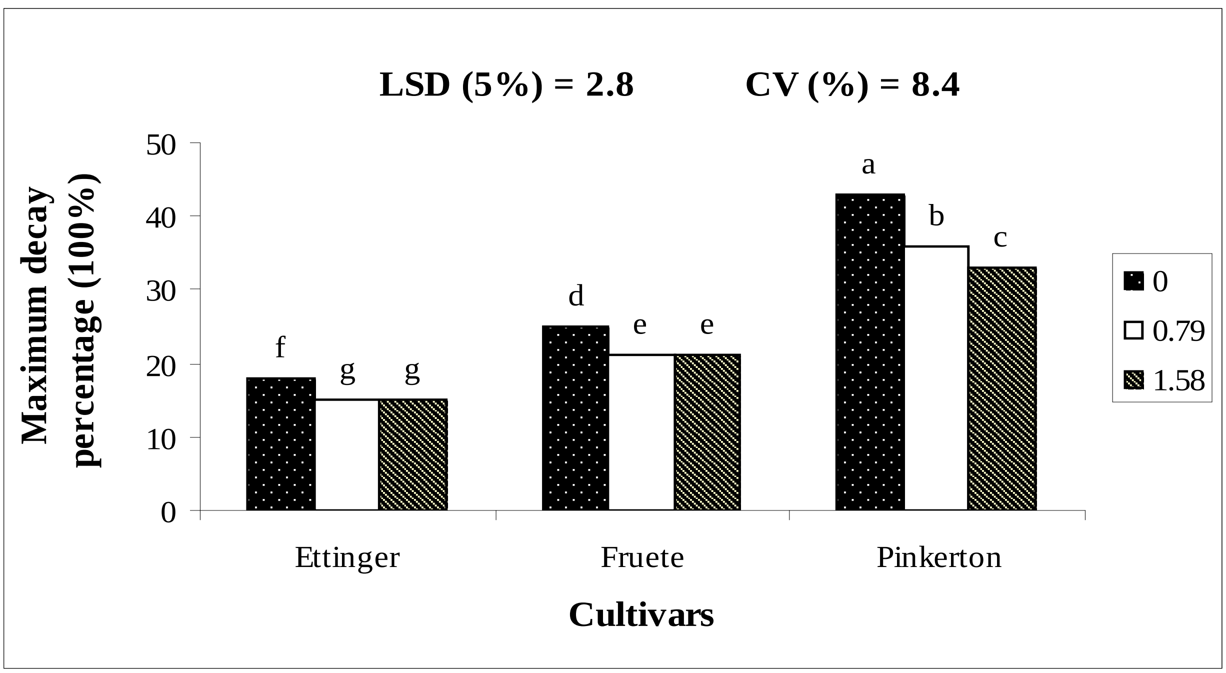

Figure 4. ***Comparison of decay percentage on the effect on selected avocado cultivars and drop height***

4.11. Time to ripen (days)

In the present work avocado fruits of the cultivar Ettinger that were dropped from a height of 0.79 and 1.58 m ripen at the 9th days of storage (*Table 10*). At day 12 all of the fruits of this cultivar in the control treatment became soft. Similarly Fuerte avocado fruits dropped from a height of 1.58 m were ripened at the 15th day of storage. At day 19 all of Fuerte avocado fruits dropped from a height of 0.79 m and those in the control group became ripe. Similarly, Pinkerton avocado fruits dropped from a height of 1.58 m ripened at the 21th day of storage. At the 25th days of storage fruits from the cultivar Pinkerton dropped from a height of 0.79 m became soft. However, Pinkerton cultivar of control treated avocado fruits were ripen on 30th day of storage time which could be edible (*Table 10*).

This result fits to the work of (Brummell and Harpster, 2001) that reported fruit softening is an important part of the ripening process, and it is well documented that change in cell walls accompany fruit softening. Similarly, in most fruit the wound site serves as an ethylene source promoting premature ripening (Kays and Paull, 2004).

*Table 10***.** Effect of dropping height and cultivar on the time to ripen

Dropping height (m)	Cultivars	Time to ripen
control		30.0^{a}
0.79	Pinkerton	25.0^{b}
1.58		21.3^{c}
control		19.0^{d}
0.79	Fuerte	19.0^{d}
1.58		15.0^{e}
control		12.3^{f}
0.79	Ettinger	9.0^{g}
1.58		9.0^{g}
LSD (5%)		0.33

CV (%)	0.91

Means with the same letter(s) in column are not significantly different.

4.12. External bruise diameter (mm)

A significant difference in bruise diameters due to the height drops and cultivars was found between 0.79 and 1.58 m *Figure 5*. However, avocados dropped from 1.58 m showed significantly larger bruise diameters, compared to avocados dropped from 0.79 m of dropping heights. The average bruise diameters obtained were between 5 mm and 25 mm from which the bruise diameters were computed. It can be seen from the results that Ettinger and Fuerte cultivar samples dropped from the height of 1.58m onto the surfaces suffered 25mm and 15mm damages respectively. However, 1.58m drop height seems to give out the greatest impact damage on the avocado fruits dropped onto surface than any other height drop used in this study followed by the 0.79m height drop. These heights are generally higher than the other. Ettinger cultivar drop height 0.79 was 12mm damage bruise diameter and Fuerte cultivar drop height 0.79m results 8mm damage bruise diameter. The control, 0.79 and 1.58m height drop for Pinkerton cultivar were ranged from 0-10 mm this inflicted that none impact damage according to Vurasvus and Ozguven (2004).

It seems that the higher meter dropped (1.58m) Ettinger and Fuerte fruit cultivars are more susceptible to impact damage than the Ettinger and Fuerte fruit cultivars at the control and 0.79m and Pinkerton cultivar at (control, 0.79 and 1.58m) drop treated fruits. This result is in accordance with Vurasvus and Ozguven (2004) that studies graded degree of impact damage in relation to average bruise diameter as follows: bruise diameter of less than 12 mm, the damage is classified as none; 12-19 mm: trace damage; 19-25 mm: slight damage; 25-32 mm: medium damage and greater than 32 mm as severe damage. According to this classification Ettinger cultivar at drop height 1.58m classified as medium damage bruise diameter, Fuerte cultivar at drop height 1.58m and Ettinger cultivar drop height 0.79m classified as trace damage bruise diameter, and Fuerte cultivar at drop height 0.79m and Pinkerton cultivar at each drop treatment classified as none damage bruise diameter.

Of all the tested treatments Pinkerton avocado cultivars was effective at all drop height followed by Fuerte avocado cultivars at control and 0.79m drop height and least effect was noticed in case of Ettinger avocado cultivars in a resistance of damage extent during storage. These differences in bruise diameter in all drop height and cultivar could be due to the stage

of ripening during impact treatment. This result fits to the works of Brusewitz *et al*. (1992) and Mandemaker *et al*. (2006) that reported avocado flesh is more easily bruised as the fruit soften and bruise severity increases with increasing impact energy. Similarly, Baryeh (2000) confirmed these findings that the avocado fruit becomes more susceptible to impact bruising with increased impact height and ripeness.

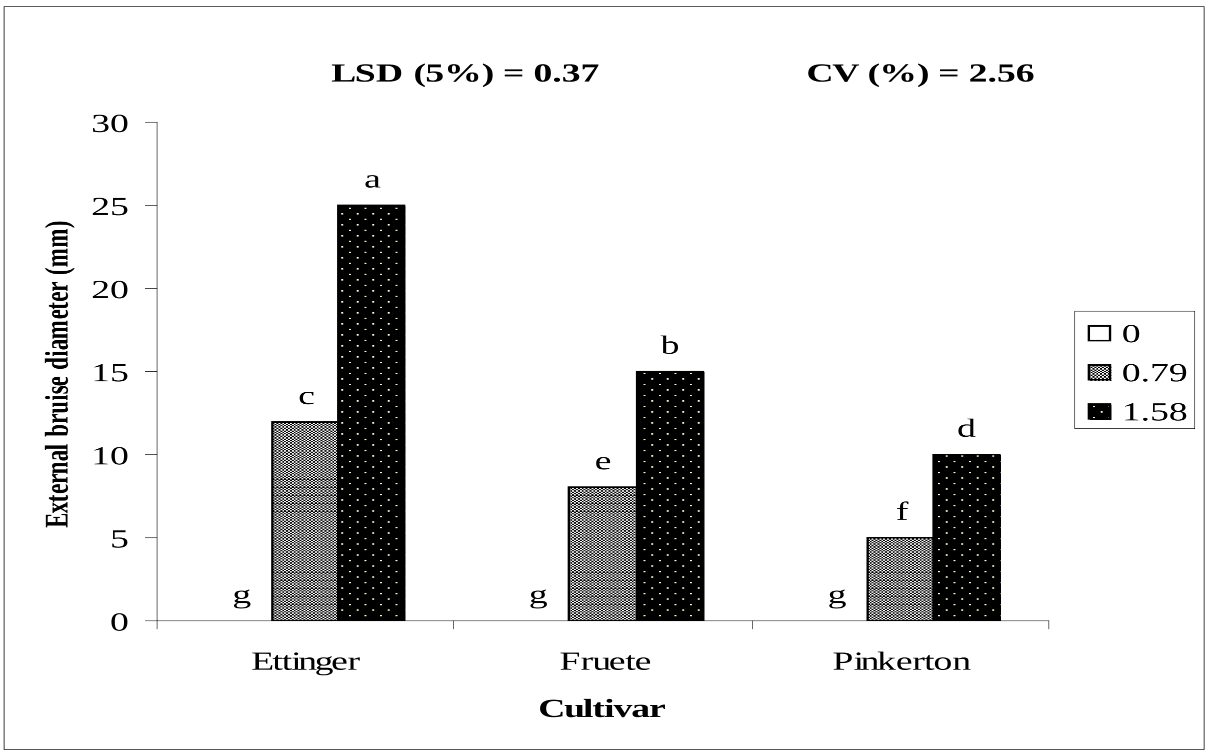

Figure 5. **Effect of drop height and cultivar on the response of external fruit bruises**

4.13 Shelf life (days)

The time period, whereby a product is not only safe to eat, but still has acceptable taste, texture and appearance after being removed from its natural environment, is defined as shelf life (Embuscado and Huber, 2009). The shelf life of Avocado fruits was considerably influenced by the dropping heights and cultivars. About 10% loss in weight is considered a reference index for termination of the shelf life (threshold level) of fruit commodities (Acedo, 1997; Pal *et al*., 1997). In the present work Ettinger cultivar drop treated (0.79 and 1.58m) avocado fruits were spoiled at the maximum of 15 days of storage. At day 18 all of the control became deteriorated. Similarly, Fuerte avocado fruits treated at 1.58m cultivars were spoiled at the 21th day of storage. At day 25 all of 0.79m and the control became unmarketable. However, Pinkerton avocado fruit cultivars treated with drop heights 1.58m were spoiled at 33th days of storage and Pinkerton avocado fruit cultivars treated with drop heights 0.79m deteriorate on 36th days of storage. Only the control one stays until 43th days of storage, which could be marketable.

Mechanical damage favors deterioration of any fruit because fresh fruits are more turgid and contain much water (about 70-80%) and also damage leads the respiration rate to be fast followed by transpiration and ethylene production (*Table 11*).

This result is related to the report of FAO (2003) transpiration, or evaporation of water from the plant tissues, is one of the major causes of deterioration in fresh horticultural crops after harvest. Similarly Rmero *et al.* (2007) reported that the presence of ethylene is not always beneficial, especially in terms of postharvest shelf life. Additionally, Mustafa Özgen *et al.* (1963) reported that a higher respiration rate appears to be associated with poor shelf life.

Similarly, Ismail (1958) reported that mechanical injury to citrus fruit increases the rate of respiration, both oxygen consumption and CO2 production are increased in injured fruit as compared to sound fruit.

Thus, the high moisture content of avocado pear is disadvantageous in terms of shelf life because oils with high moisture content are not able to be preserved for a longer period (Orhevba and Jinadu, 1978).

Table 11. Effect of dropping height on the shelf life of selected cultivars

Drop height (m)	Cultivars	Shelf life (days)
control		43.0[a]
0.79	Pinkerton	36.0[b]
1.58		33.6[c]
control		25.0[d]
0.79	Fuerte	25.0[d]
1.58		21.0[e]
control		18.0f
0.79	Ettinger	15.0[g]
1.58		15.0[g]
LSD (5%)		0.33
CV (%)		0.75

Means with the same letter (s) in a column are not significantly different

5. SUMMARY AND CONCLUSION

Avocado being a highly perishable fruit possesses very short shelf life and reaches to respiration peak of the ripening process. To prevent high postharvest losses, especially in developing countries, like Ethiopia, where losses are very high, adopting simple technologies could be beneficial to prevent the losses.. In view of easy adoption and sustainability of technologies, the use of proper handling could be a good alternative since it is simple, low-cost and environmentally friendly alternative technology for both extending postharvest life and keeping quality. The additional benefit conferred by proper handling is that these are easy practices and are not financially synthesized. The present investigation was directed towards understanding differences among three avocado varieties in tolerating mechanical damage, by employing a dropping height test.

Results of the present study showed that Ettinger and Fuerte avocado cultivars dropped from 1.58 and 0.79 m possess trace bruise damage against the test drop height, *mechanical damage*, which makes serious postharvest loss. The degree of damage was found to be dependent on the drop height and the cultivar. Among the three varieties, fruits of the Pinkerton cultivar have more resistance to mechanical damage when dropped from a height of 0.79 and 1.58 m above the ground, followed by fruits of Fuerte and Ettinger.

The difference in resistance of the fruits of different avocado cultivars could be attributed to their cell composition that makes them resistant to mechanical damage during dropping time. It is evident from the results that some of the drop height and cultivars showed minimum bruise area on the mechanical damage. Among the dropping heights examined, control and 0.79 m proved to be effective in handling test, when applied at all cultivars. It showed the minimum percent bruise area (none and trace damage) compared with the other treatments at day 18 of storage and reduced the extent of damage to the fruits. The extent of damage inclined when higher dropping heights were used.

In brief in this study, it was observed that dropping height of avocado fruits using different cultivars can significantly accelerates changes in different quality attributes such as weight loss, firmness, total color change, TA, TSS, pH, ripeness external bruise area and decay which all together decrease the shelf life of fruits during ambient storage temperature compared with controlled fruits.

It can thus be concluded that among the drop height used, Pinkerton cultivar proved to be effective at a drop height at the control, reduced the development of mechanical damage, maintains the freshness of the avocado fruit, and increases its shelf life for up to 43 days of storage at ambient temperature without affecting the physico-chemical properties.

Therefore producers, wholesaler traders, any market chains and consumers could easily adapt the technology to treat and handle fresh, mature Ettinger, Fuerte and Pinkerton avocado fruits in order to increase their shelf life. Ettinger, Fuerte and Pinkerton avocado fruits treated in this way could also be shipped long distance without affecting its quality if treated or handled carefully with appropriate type of cultivar and drop heights.

Generally, short shelf life of avocado fruit because of high perishability and mechanical damage is enormous public problem, but it could be controlled by the use of proper handling such as the controls.

The fact that many avocado fruits possess less antimicrobial activity has been proved after the fruit is harvested and the pathogen penetrate. The type the cultivar and dropping height depends on the commodity used and against which species of bacteria or fungi it is affected. However, avocado susceptibility is regulated by more than one mechanism: a decrease in the level of antifungal compounds and an increase in pericarp pH which modulates pectolytic (PL) secretion. Component in this complex process can be attributed to the physiological and biochemical changes that occur in the host during ripening and senescence and that lead to decreased host response and increased susceptibility.

If dropping heights are expected to be minimized the bruise, the physico-chemical property and organoleptic impact should also be considered for the use of proper handling can alter the quality of the fruits. Problems that may occur if higher dropping heights are used such as discoloration and change in flavor.

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7. APPENDICES

Appendix Table 1: Vitamin and minerals content of the avocado (nutrients per 1 cup ripe, edible)

Vitamin and mineral	Amount (%)
Vitamin A	4
Vitamin C	24
Vitamin B-6	20
calcium	1
Iron	4
Magnesium	10

Yokoyama et al., 1991

Appendix Table 2: Means squares for the variance of the effects of drop height on Ettinger, Fuerte and Pinkerton cultivars and quality parameters of treated avocado fruits

source	DF	PLW (%)	Firmness	Pulp to peel ratio	Peel color (Chroma)	TSS	TA	PH	Dry matter (%)	Decay or rotting percentage (%)	Crude fat content (%)	Time to ripen (day)	External bruise area (mm)
cultivar	2								**				
Dropping height	2												
Dropping height*c	4	**	**	**	**	**	**	**	NS	**	**	**	**

ultivars													

*, ** and Ns: significant at (p<0.05, p<0.01) and not significant, respectively

Appendix Table 3: Overall ANOVA for physiological weight loss (%)

Source of variation	DF	Mean square	F value	Pr >F
cultivar	2	48.03929259	597.56	<.0001
Dropping height	2	0.01564815	0.19	<.0001
Cultivar*Dropping height	4	0.01904815	0.24	<.0001

CV (%) = 0.23

Appendix Table 4: Overall ANOVA for pulp to peel ratio

Source of variation	DF	Mean square	F value	Pr >F
cultivar	2	279.1944444	10051.0	<.0001
Dropping height	2	105.2500000	3789.00	<.0001
Cultivar*Dropping height	4	6.3194444	227.50	<.0001

CV (%) = 0.17

Appendix Table 5: Overall ANOVA for firmness (N)

Source of variation	DF	Mean square	F value	Pr >F
cultivar	2	379006.8270	11743.7	<.0001
Dropping height	2	9593.5226	297.26	<.0001
Cultivar*Dropping height	4	1071.6965	33.21	<.0001

CV (%) =1.81

Appendix Table 6: Overall ANOVA Total Soluble solids (^{0}Brix)

Source of variation	DF	Mean square	F value	Pr >F
cultivar	2	23.16259259	269.56	<.0001
Dropping height	2	9.05592593	105.39	<.0001
Cultivar*Dropping height	4	2.47425926	28.80	<.0001

CV (%) = 6.22

Appendix Table 7: Overall ANOVA Titratable acidity (%)

Source of variation	DF	Mean square	F value	Pr >F
cultivar	2	0.00013704	3700.00	<.0001
Dropping height	2	0.00001737	469.00	<.0001
Cultivar*Dropping height	4	0.00000170	46.00	<.0001

CV (%) =3.9

Appendix Table 8: Overall ANOVA for PH (%)

Source	DF	Mean square	F value	Pr >F
Cultivar	2	1.024	571.07	<.0001
Dropping height	2	0.049	27.19	<.0001
Cultivar*Dropping height	4	0.054	29.88	<.0001

CV (%) = 0.28

Appendix Table 9: Overall ANOVA dry matter (%)

Source	DF	Mean square	F value	Pr >F
Cultivar	2	3.03370	8191.00	<.0001
Dropping height	2	0.00037	1.00	0.3874
Cultivar*Dropping height	4	0.00037	1.00	0.4332

CV (%) = 0.09

Appendix Table 10: Overall ANOVA storage life (days)

Source	DF	Mean square	F value	Pr >F
cultivar	2	1900.48	51313.0	<.0001
Dropping height	2	62.48	1687.00	<.0001
Cultivar*Dropping height	4	10.31	278.50	<.0001

CV (%) = 0.75

Appendix Table 11: Overall ANOVA crude fat determination (%)

Source	DF	Mean square	F value	Pr >F
cultivar	2	533.12	19992.0	<.0001
Dropping height	2	82.87	3107.68	<.0001
Cultivar*Dropping height	4	1.36	51.31	<.0001

CV (%) = 0.49

Appendix Table 12: Overall ANOVA time to ripen (days)

Source	DF	Mean square	F value	Pr >F
cultivar	2	536.70	14491.0	<.0001
Dropping height	2	61.37	1657.00	<.0001
Cultivar*Dropping height	4	10.20	275.50	<.0001

CV (%) =0.91

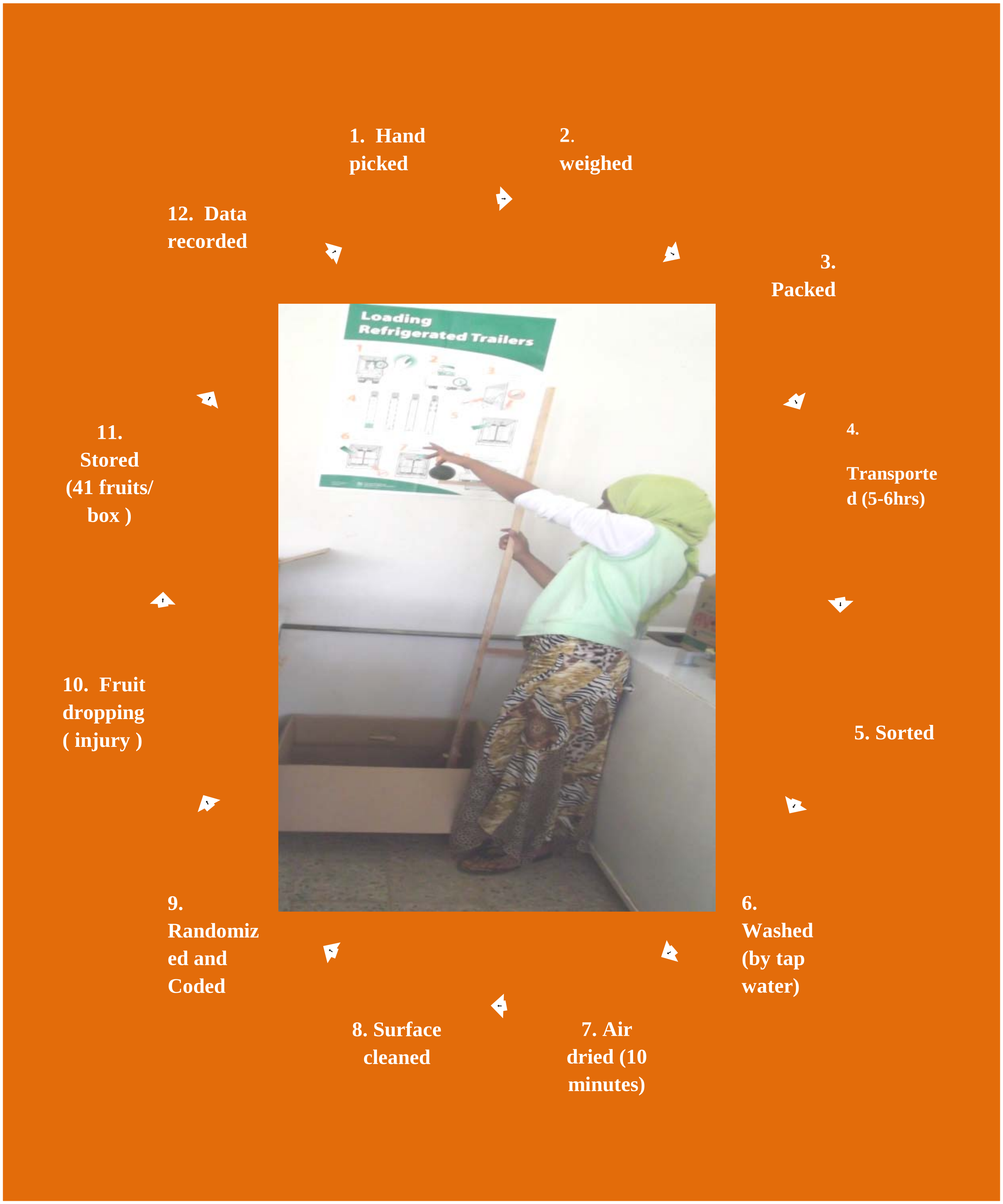
Appendix Table 13: Overall ANOVA color (Chroma value)

Source	DF	Mean square	F value	Pr >F
cultivar	2	19837683.8	763.33	<.0001
Dropping height	2	7330159.9	282.06	<.0001
Cultivar*Dropping height	4	1296829.6	49.90	<.0001

CV (%) =1.52

*Appendix figure 1***.** Dropping of avocado fruits from the average height of Ethiopian male height which is 1.58m in the local avocado storage of Jimma Town (a, b and c), Dropping of avocado fruits from the half of average height of Ethiopian male height which is 0.79m in the local storage of Jimma Town (d, e and f), The women sort her own need and thrown other avocado fruits on the floor of storage room at Jimma town (g) and mechanically damaged fruit which selected and obtained from the current storage room at Jimma town(h)

Appendix figure 2. Fruit ready to drop from the height of 1.58m on the prepared stationary pole (A) Allowing the fruit to fall freely on the height of 1.58m from the stationary pole (B) fruit bounded and fruit failed after drop treatment of the assigned height (C)



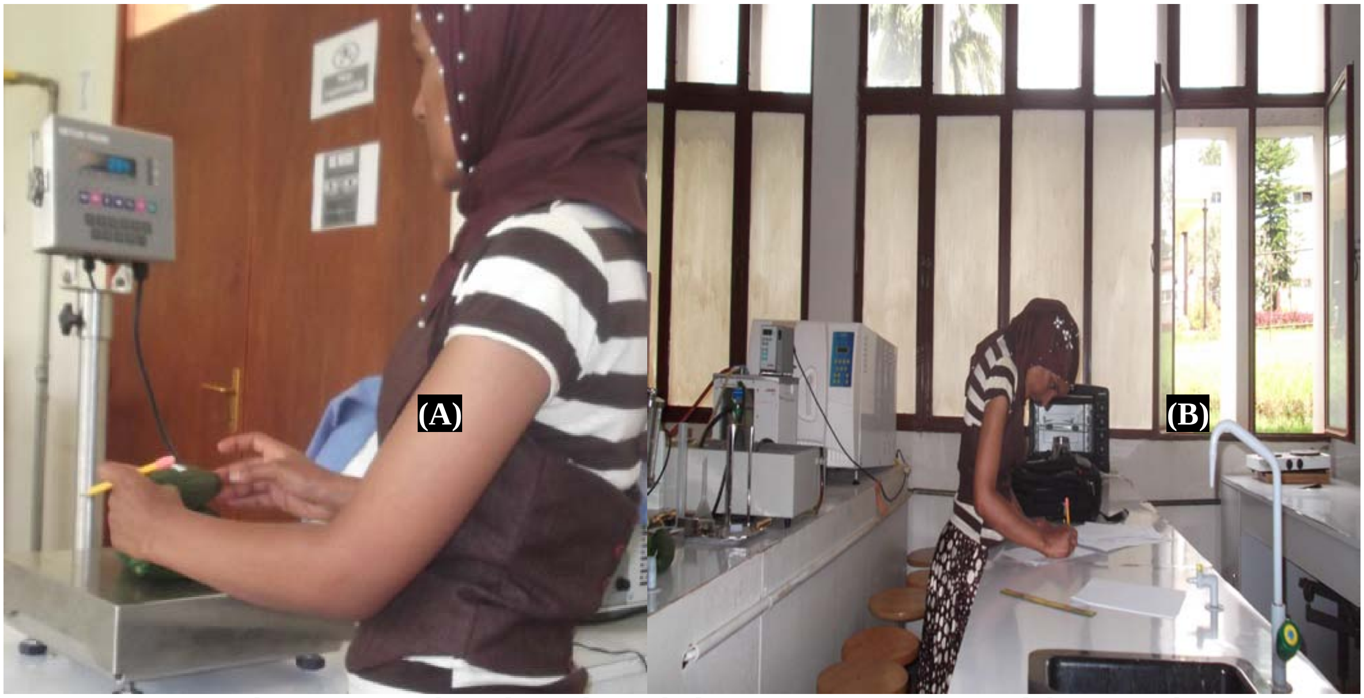
Appendix Figure 3. Schematic description of experimental procedure for avocado fruit dropping impact study

Appendix Figure 4. Hand picking of the three avocado cultivars at Melkassa Agricultural Research Center (MARC)

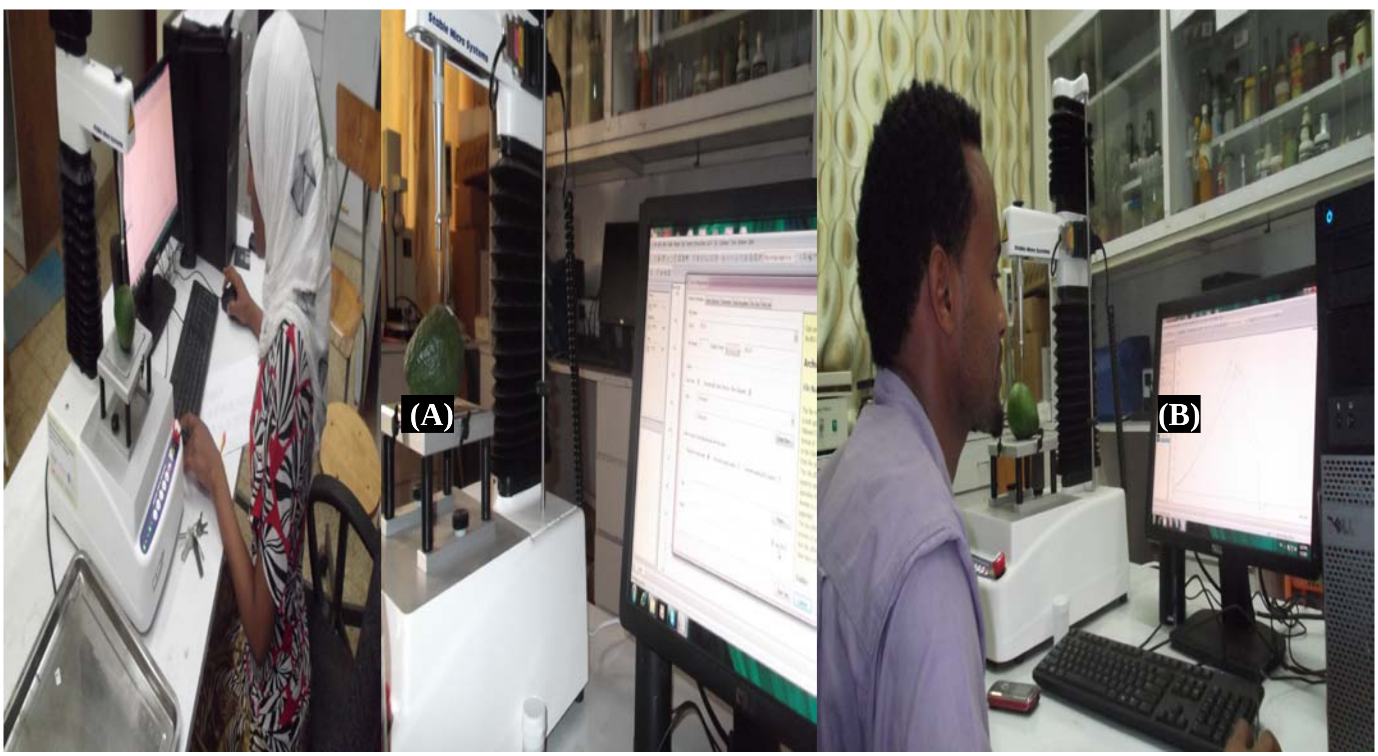
Appendix Figure.5. Pitting of the prepared carton for proper aeration during storage (A) and the pitted carton box sample (B)

Appendix Figure.6. Coding of the avocado cultivars before the fruit is injured (A) and fruits after coded (B)

Appendix Figure.7. Dropping of individual fruit from the height of 0.79m from the stationary pole (A) Dropping of individual fruit from the height of 1.58m from the stationary pole (B) Fruit fall after drop treatment from the assigned height in the bounded carton box (C)



Appendix Figure.8. Physiological weight loss measurement (A) and data recording (B)



Appendix Figure 9. Testing of avocado fruits using computerized TA-XT plus software (A) and (C) output readings noted on the computer reading chart, to one decimal place(B)

Appendix Figure10. Preparing of avocado fruits to weigh the pulp and the peel separately by removing the stone(seed) part of the fruit to had the ratio of the pulp to peel result (A) Reading of the output results peel noted on the balance reading screen, to one decimal place (B)

Appendix Figure. 11. Dried sample sheathed with aluminum sheet (A) and data recording of the results (B)

Appendix Figure 12. Data measurement on color of the fruits using hand held color meter (A) and decay percentage of Ettinger avocado fruit cultivar sample of drop height 1.58m on the last day of storage(B)