Effect of Calcium Chloride Pretreatment And Packaging Materials On Shelf Life And Quality Of Avocado (*Persia americana M.)*

M. SC. THESIS

JEMAL HAJI

HAWASSA UNIVERSITY

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Effect of Calcium Chloride Pretreatment and Packaging Materials on Shelf Life and Quality Of Avocado (*Persia americana M.)*

JEMAL HAJI KULU

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APPROVAL SHEET

As Thesis research advisor, I hereby certify that I have read and evaluated this Thesis prepared under my guide, by JEMAL HAJI Entitled: "***Effects of Calcium Chloride Pretreatment and Packaging Material on Shelf Life and Quality of Avocado (Persia americana M.)''.***

I recommend that it be submitted as fulfilling the Thesis requirement.

ALI MOHAMMED (PhD)	____________________	________________
Major Advisor	Signature	Date
BEZUAYEHU TESFAYE (PhD)	____________________	________________
Co-Advisor	Signature	Date

As member of the *Board of examiners* of the M.Sc Thesis Open Defense Examination, we certify that we have read, evaluated the thesis prepared by JEMAL HAJI and examined the candidate. We recommended that the Thesis be accepted as fulfilling the thesis requirement for the degree of Master Science in Agriculture (Horticulture).

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Chairman	Signature	Date
________________________	__________________	________________
Internal Examiner	Signature	Date
________________________	__________________	________________
External Examiner	Signature	Date

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Above all, I did all things with the strength ALLAH gave me!!

DEDICATION

This Thesis is dedicated to my wife Geno Hussien who brought me up and to my son Fenet Jemal.

STATEMENT OF THE AUTHOR

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Name: Jemal Haji Signature____________

Place: Hawassa University, Hawassa

Date of submission_______________

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AA	Ascorbic Acid
ACC	1-Amino-1-Cyclopropane Carboxylic Acid
AM	Ambient
ANOVA	Analysis of Variance
AOAC	Association of Agricultural Biochemists
CA	Controlled Atmosphere
EARO	Ethiopian Agricultural Research Organization
EC	Evaporative Cooling
FAO	Food and Agricultural Organization
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
LSD	Least Significant Difference
MA	Modified Atmosphere
MAP	Modified Atmosphere Packaging
P	Probability level
PE	Polyethylene
PG	Polygalacturonase
PME	Pectin Methyl Esterase
PWL	Physiological Weight Loss
RCBD	Randomized Complete Block Design
SSC	Soluble Solid Concentration
TSS	Total Soluble Solid
TA	Titratable Acidity
TS	Total Sugar
WVPD	Water Vapor Pressure Deficit

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***By*: *Jemal Haji* (*Msc. In Horticulture*)**
***Major Advisor*: *Ali Mohammed* (*PhD*)** *Jimma University, Jimma, Ethiopia.*
***Co-Advisor*: *Bezuayehu Tesfaye* (*PhD*)**, *Hawassa University, Hawassa, Ethiopia.*

ABSTRACT

An experiment was conducted at Hawassa University food science laboratory in 2012 at ambient temperature to assess the effect of packaging material and calcium chloride pre-treatment on post harvest shelf life and quality of avocado (Persia americana M.) at ambient temperature (24±2ºC) and relative humidity of 69.7%) during storage. The treatment included factorial combinations of four packaging materials. high density polyethylene (HDP), low density polyethylene (LDP), paper bag (PB) and control, and calcium chloride concentration of (0%, 2%, 4%, 5% and 6% W/V using CRD with three replications. Weight loss, firmness, marketability, dry matter content, decay, Total Soluble Solids (TSS), pH, Titratable Acidity (TA), of avocado were studied at an interval of 3 days (0, 3rd, 6th, 9th, 12th and 15th day). The result showed that avocado fruits packed in HDP, LDP and paper bag having 6% $CaCl_2$ had significant effect ($p<0.05$) on overall quality and postharvest shelf life except decay, pH and dry matter content. Also, results showed that 6%$CaCl_2$ treated fruit packed in HD polyethylene, LD polyethylene and paper bag had minimum weight loss (1.46 %), firmness, marketability, decay, lower TSS (7.24%), lower pH (4.88%), and higher retention of TA (0.23%) at ambient temperature during storage. On the other hand the control fruit had highest values of loss of firmness, marketability, dry matter content, and weight as well as decay loss, TSS, pH, and lowest TA (0.19%) respectively during storage. The 6%$CaCl_2$ treated fruit and packed in HD polyethylene, LD polyethylene and paper bag had minimum weight loss, firmness, marketability, decay, and slower increase of TSS, pH, and higher retention of acidity respectively of fruit during the storage period. These study indicated that avocado fruit treated with 6%$CaCl_2$ had played a significant role on quality and post harvest shelf life of avocado by delaying the ripening process and with a minimum quality loss during 15 days of storage as compared to the control avocado fruits that had greater compositional changes with maximum quality loss and shorter postharvest life during storage at ambient temperature.

Keywords: *Postharvest life, Packaging, calcium chloride weight loss, firmness*.

1. INTRODUCTION

Ethiopia is agro-ecologically diverse and many parts of the country are suitable for growing temperate, sub-tropical and tropical fruits. For example, substantial areas in the southern and south-western parts of the country receive sufficient rainfall to support fruits adapted to the respective climatic conditions. Moreover, Ethiopia has potentially irrigable area of 3.5 million ha with net irrigation area of about 1.61 million ha of which currently only 4.6 % is utilized (Amer, 2002). Despite this potential, the area under fruits is very small and mainly smallholder based. According to the MoARD (2005), there are about 3 million farmers involved in fruit production with a total area of about 43,500 ha and producing about 261,000 tons of fruits annually. However, less than 2 % of all the produce is exported owing to the fact that each farmer grows very few trees of unimproved varieties which are also poorly managed and are mainly for home consumption, except banana production in the south Ethiopia (Joosten, 2007). These fruits are typically cultivated to supplement households' income from their main crops. The few state owned farms with about 3,000 ha mainly grow tropical fruits (banana, avocado, mango, orange, and papaya) and are mainly located in the eastern Rift Valley (Siefu, 2003).

In spite of the great potential Ethiopia has, the fruit industry has not been contributing much to the economy of the country. Compared with other developing countries, production and consumption of fruits is relatively low in Ethiopia (Emana and Gebremedhin, 2007). In addition to production problems, postharvest technologies have not been developed for most of the major fruit crops. Marketing of fruits and vegetables in Ethiopia is complicated by high postharvest losses which are estimated to be as high as 25-35% (Tadesse, 1991). It has also been estimated by the FAO (2005) that the postharvest loss of perishable commodities in Ethiopia is as high as 50%. This high loss has been attributed to several factors among which lack of packaging and storage facilities and poor means of transportation are the major ones (Kebede, 1991; Wolde, 1991). In spite of this, very little emphasis was given to research on postharvest handling of perishable produce (Tadesse, 1991; Tilahun, 2002). The postharvest losses could discourage farmers from producing and marketing fresh produce and limit the urban consumption of fresh fruits and vegetables. Hence, development of appropriate and affordable postharvest technologies is believed to make great contribution to improve quality and use of these crops.

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 affects the growers' income, but also reduces the country's export and local market volumes, food required to feed the country's population and it is also a waste of resources used in production. Avocado fruits incur large (about 40%) losses during postharvest handling (Wasilwa *et al*., 2005). leading to reduced fruit quality particularly skin color (Anjum and Ali, 2004). Change in skin color usually results from an initial decrease in chlorophyll content, followed by an increase in the levels of the anthocyanin, andcyanidin 3-O-glucoside (Katy *et al*., 2007).

Shelf life is defined as the period in which a product should maintain a predetermined level of quality under specified storage conditions (Perez *et al*., 2004). Reduction of the losses in a systematic way requires knowledge of postharvest physiology, its applied technical aspect, handling and the appreciation of its biological limitation represented as storage potential (Nakasone and Paull, 1999). Packaging and handling systems have been developed in many countries to move products from farm to consumer expeditiously in order to minimize quality degradation. Packaging fruits is one of the most commonly used postharvest practice that puts them into unitized volumes which are easy to handle while also protecting them from hazards of transportation and storage (Burdon, 2001). Modified atmosphere packaging for storage and transportation of fruits and vegetables is commonly achieved by packing them in plastic films. Storage in plastic films with different kinds of combinations of materials, perforation and inclusions of chemicals and individual seal packaging are types of modified atmosphere storage (Burdon, 2001; Irtwange, 2006).

Flexible packs are plastic films characterized for having a high mechanical resistance to traction, perforation and low temperatures, in addition to presenting appropriate durability and they lend themselves to effective closure. Some of the main materials used for the elaboration of flexible packs are: High density polyethylene (HDPE), Polyvinyl chloride (PVC), Polypropylene and Polyamides (Cortez, 2004). Nevertheless, neither the type of packaging material nor the storage period affect texture, presentation (appearance), color and odour of the product (Ormazabal, 1999, Arze, 1993, Soliva-Fortuny *et al*., 2002, Sierra 2004, and Nemesny, 2005) indicated that the physical appearance (presentation and colour) of the Fourth Range products suffers minimal variations for until a period of 7 to 10 days, provided that the balance of the atmosphere inside the packaging is not affected.

Avocado fruits treated with NaOCl, wax or $CaCl_2$ had reduced blemishes on their surface due to lower rate of disease incidences and severity (Hopkirk *et al.,* 1990) and enhanced cell wall by calcium (Joyce *et al*., 1997). Calcium Chloride conserves the qualities of fruits, prevented physiological disorders, reduces the rate of respiration, lessens the solubilisation of pectin substance, maintaining the firmness and slows down the ripening process (Burns and Pressey, 1987; Salunkhe and Desai, 1984; Magee *et al*., 2002). Polyethylene bags maintain high humidity, reduce loss of weight and consequently slow down the drying process (De-Souza *et al*., 1999). It maintained the organoleptic properties of fruits (Kolev, 1977).

According to findings of assessment by Tadesse (1991), high postharvest losses makes marketing of fruits and vegetables in Ethiopia very complicated and losses are estimated to be as high as 25-35%. It has also been estimated by the FAO (2005) that about 50% of perishable commodities in Ethiopia is lost after harvest. It is repeatedly reported that the huge loss of the fragile crops is related to the poor varietal selection, lack of appropriate packaging and storage methods. Furthermore, poor post-harvest handling throughout the chain and transportation and processing facilities also do have paramount effects on the post-harvest loss of fruit and vegetable crops in the country. Though this is the fact research on post-harvest technology of perishables is so far very poor (Tilahun, 2002). Therefore, the purpose of this study was to investigate the effect of packaging material and treatment with calcium chloride on post-harvest shelf life of avocado.

Specific objectives of this study were:

- To identify the best packaging material that maintains better post-harvest quality parameter and shelf life of avocado fruits
- To determine the effect of pre-treatment with calcium chloride on post-harvest quality and to evaluate the interaction effect of packaging material and treatment with calcium chloride on post-harvest shelf life of avocado fruits

2. LITERATURE REVIEW

2.1 The Avocado Crop

Avocado (*Persea americana* M.) is a tropical fruit that belongs to the family Lauraceae and is native to tropical America (Griesbach, 2005). Avocado tree grows throughout the year but fruit bears between March to September. Avocado is grown under diverse climatic conditions. The growers include large states who accounts for 15% and small-scale farmers who accounts for the bulk (85%) of avocado mainly for subsistence, local markets and export (Cooper *et al*., 2003).

According to FAO (2009), Avocado has a long history of production and consumption especially in Mexico, and North and Central America. In line with this FAO (2007) reported that, world production of avocado was 3,222,069 metric tons valued at $606,608,000 and in 2007, the leading producer was Mexico followed by Indonesia and United States of America. Leading exporters are Mexico and Chile with Israel facing hard competition on European markets from Spain and South Africa (Market Research Analyst, 2008).

Private orchard owners in Hirna and Wondo-genet first introduced avocado in to Ethiopia in 1938. Gradually, its cultivation spread nationwide with satisfactory adaptation to different agro-ecologies most western part of Ethiopia provides favourable weather condition for avocado cultivation (Ettisa, 1999). Despite the favourable weather condition, Avocado was unknown to both producers and consumers in south western Ethiopia before two decades. In 1979, a collection orchard was established by planting few collections. When these trees started bearing, more seeds were planted to promote genetic recombination. That was how utilization of avocado fruits was started in Jima, Metu, Gera, Tepi and Babeka areas. Presently, there is great demand for avocado in southern part of the country (Edossa, 1997).

2.2. Pre-harvest factors that affect avocado fruit quality

2.2.1. Water stress

Water stressed ‘Hass’ avocado trees were found to bear more elongated fruit (Yahia, 2002). The reason for this is unknown and further studies are required to investigate this phenomenon. Water stress reduces the internal quality of avocados due to the increased activity in polyphenol oxidase leading to browning of the flesh. Lower concentrations of calcium were found in water stressed fruit resulting in high incidence of physiological disorders.

Adato and Gazit (1974) found that pre-harvest water stress resulted in premature fruit abscission and an increase in ethylene production leading to accelerated ripening by 40% and 25% depending on the degree of water stress. Both Kaluwa (2010) and Blakey (2011) confirm that water stress decreased the normal avocado ripening time hence reducing the shelf life accompanied by an increased risk of physiological disorders. The effect of water stress on avocados can further be linked to temperature. When a plant is water stressed, the temperature of the fruit rises because cooling is as a result of water movement through the fruit stalks (Woolf and Ferguson, 2000). Once the fruit is harvested this cooling effect is halted and the rise in temperature is often further exacerbated by exposure to the sun.

2.2.2. Plant nutrition

The influence of nutritional practices on avocado fruit quality is confusing but overall, research has indicated that the nutritional status of the fruit can impact the post harvest quality of the fruit. Previous work suggested that avocado fruit quality appears to be primarily affected by calcium (Kremer-Köhne *et al*., 1993) and secondarily by nitrogen (Arpaia *et al*., 1999), magnesium, potassium (Koen *et al*., 1990; Witney *et al*., 1990), and zinc (Vorster and Bezuidenhout, 1988). Extensive research on ‘Fuerte’ avocado has been conducted in South Africa. This research focused on the relationship of post harvest avocado fruit quality and the role of plant nutrition. Witney *et al*.

(1990) demonstrated the impact of fruit Calcium levels on fruit ripening duration. The researchers reported that a significant interaction between these two variables, with high Calcium fruit taking longer to ripen. The authors also reported on fruit Calcium levels during fruit growth from vigorous vs. non vigorous trees for both ‘Hass’ and ‘Fuerte’. In both cases, fruit borne on non vigorous trees had higher Calcium levels, especially during the early stages of fruit growth. This period also correlates with the time of maximal vegetative flushing. The researchers also suggested that it is the early levels of Calcium in the fruit that influence subsequent post harvest fruit quality. The work of Whiley *et al*. (1992) has confirmed this observation.

2.2.3. Harvesting

Avocados, unlike other fruit do not mature and ripen on the tree, but only once harvested (Ozdemir and Topuz, 2004; Perez *et al*., 2004; Gamble *et al*., 2010; Osuna-Garcia *et al*., 2010). 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, flavourless, shrivelled, blackened fruit (Gamble *et al*., 2010 and Osuna-Garcia *et al*., 2010) 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).

The time of harvesting among other factors depends on the avocado cultivar. Whiley *et al*. (1996a) showed that early harvesting at 21% and 24% dry matter lead to a higher cumulative and average yield in the early-maturing variety ‘Fuerte’. However, delaying harvesting till a value of 30% dry matter was attained, reduced yields by 26% and lead to alternate bearing. Similar studies by Whiley *et al.* (1996b) indicated that early harvesting of late-maturing variety ‘Hass’ at 25-30% dry matter resulted in high productivity whereas delayed harvesting till 35% dry matter, reduced yields leading to alternate bearing. Chen *et al*. (2009) observed that late season 'Sharwil' were smaller in size, had higher oil content and dry matter and demonstrated a shorter shelf life than early and mid-season fruit.

Hofman *et al*. (2002a) recommends that picking of wet avocados be avoided as this increases the incidence of cold injury, pulp spot and lenticel damage. Fruit harvested in the morning or late afternoon tend to have less field heat. Colour, size or oil content, generally serve as indications as to the most appropriate time for harvesting (Ozdemir and Topuz, 2004).

Harvesting is mainly accomplished by manual techniques such as clipping and snapping. Eaks (1973) investigated the influence of these two methods on the postharvest development of avocados and found no significant difference in terms of weight loss and the rate of ripening. Yahia (2002) states that clipping aided in reduced bruising and puncturing of adjacent fruit while in containers and reduced the onset of stem end rot. However, Hofshi and Witney (2002) disagree with the use of clipping by referring to studies that indicated snapped avocados ripened at a faster rate than those that were clipped. Further studies are required to establish the effect of snapping and clipping on the consequent quality of avocados.

Avocados are picked by hand using special clippers and ladders. Once picked, avocados are pre-cooled overnight to remove field heat in the packinghouse to ensure the quality. Before packaging, avocados are washed, lightly cleansed, sized, and graded for quality. The highest grade is separated for supply to supermarket for raw consumption; others are used for processing. The packed avocados are maintained at optimum cool temperature to ensure ripeness and quality while awaiting shipment. Once picked, avocado ripens quickly at room temperature because of the production of ethylene gas during storage. All these steps from picking to grading take 5-9 days (Feng *et al.,* 2000). Skin of avocado fruits changes its color upon ripening; for example, Hass avocados change color from green to purple to black. It is important to sort avocados in lots of different ripening stages and employ postharvest measures to extend shelf life and quality, as ethylene production from some avocados in a lot can trigger ripening which once initiated, is hard to stop (Mizrach *et al.*, 1991).

2.3. Postharvest Physiology of Avocado fruit

2.3.1. Respiration and ripening

Respiration is described as a natural process occurring within all living organisms whereby organic materials such as carbohydrates, proteins and fats are broken down. During respiration, oxygen is expended and carbon dioxide liberated accompanied by the production of energy in the form of heat (Workneh and Osthoff, 2010). Ethylene is a plant hormone that is naturally produced by avocados. Both respiration and ethylene formation are, predominantly, responsible for the ripening of avocados. Jeong *et al*. (2003), Workneh and Osthoff (2010) and Wu *et al*. (2011) describe avocados as being climacteric, characterised by a surge in ethylene production at the start of ripening. The respiration of avocados follows three characteristic climacteric phases *viz*. preclimacteric minimum of least respiration, climacteric maximum of highest respiration and a post climacteric phase synonymous with a decline in respiration. It is during the preclimacteric and climacteric phases where much of the changes associated with ripening occur (Perez *et al*., 2004). The shelf life of fresh commodities is inversely related to respiration and ethylene rates as stated by Perez *et al*. (2004). An increase in the respiration rate hastens senescence contributing to flavour loss and reduced dry weight (Workneh and Osthoff, 2010). Therefore, different handling methods, especially those associated with lowering respiration rates should be favoured.

During the respiration process there is a loss of stored food reserves in the commodity. This leads to hastening of senescence because the reserve that provides energy is exhausted (Wills *et al*., 1989; Paull, 1993; Kays, 1997). The energy released as heat could affect postharvest technology considerations, such as estimations of refrigeration and ventilation requirements. The rate of respiration of harvested commodities is inversely proportional to the shelf life of the product; a higher rate decreases shelf life (Lee *et al*., 1995). Respiratory activity is markedly affected by temperature and modified atmosphere. Respiration rates alter during a commodity’s natural process of ripening, maturity and senescence (Desi and Wagh, 1995; Irtwange, 2006).

Climacteric fruits experience a marked and transient increase in respiration during their ripening which is associated with increased production and sensitivity to ethylene. The sudden increase in respiration is called the 'climacteric rise', which is considered to be the turning point in the life of the fruit. After this, the senescence and deterioration of the fruit begin. To extend the postharvest life of climacteric fruits their respiration rate should be reduced as far as possible (Paull, 1993; Irtwange, 2006).

Generally, the loss of freshness of perishable commodities depends on the rate of respiration. An increase in respiration rate hastens senescence, reduces food value for consumers and increases the loss of flavour and salable weight. The loss of substrate from stored plant products results in a decrease in energy reserves within the tissue, which in turn decreases the length of time the product can effectively maintain its existing condition (Kays, 1997; Tilahun, 2002).

2.4. Post Harvest Handling of Avocado

2.4.1. Storage Temperature

Temperature is the most crucial factor to consider in storage of fruit due to its involvement in biological processes (Workneh *et al*., 2011b). Low temperature storage hinders the respiration rate and ethylene production, resulting in retarded metabolic rates and an extended shelf life (Hofman *et al*., 2002a; Perez *et al*., 2004; Workneh; Osthoff, 2010; Getinet *et al*., 2011 and Wokneh *et al*., 2011a). Theoretically, for every 10°C increase in temperature a resultant doubling in the rate of respiration occurs (Workneh and Osthoff, 2010).

Zauberman and Jobin-Decor (1995) found that storage at 5°C and 8°C resulted in early ripening and mesocarp discolouration. Perez *et al*. (2004) reports the optimum storage temperature for unripe avocados to be 5-13°C and 2-4°C for mature avocados resulting in two to four weeks of shelf life, depending on the cultivar. If mature avocados were stored at 5-8°C, the shelf life would be reduced to one to two weeks. According to Hopkirk *et al*. (1994) cool stored avocados at 6°C thereafter ripened at 15°C was most effective in enhancing the fruit quality. This compares with findings by Meir *et al*. (1995) which state that temperatures between 5°C and 7°C yield successful results in prolonging the shelf life of 'Hass' by five to nine weeks. A combination of 7°C with 2% oxygen and 4% carbon dioxide extended the storage time to nine weeks (Zauberman and Jobin-Decor, 1995). Storage at 2°C proved to be more successful as the fruit remained unripe for up to four weeks and ripened as per normal when transferred to the 22°C without injury.

Van Rooyen and Bower (2006) discovered that storage of 'Pinkerton' at below the recommended temperature of 5.5°C reduced the severity of mesocarp discoloration thought to be due to chilling injury, while storage at temperatures above 8°C intensified the disorder. Cold storage increased the occurrence of mesocarp discoloration and became more pronounced with increasing maturity

(Cutting *et al*., 1992). Too high temperatures are also undesirable with fruit failing to ripen adequately and proliferation of postharvest disorders at 30°C and 25°C as compared to a ripening temperature of 20°C Hopkirk *et al*., (1994). Flitsanov *et al*. (2000) demonstrated the effect of temperature on the firmness of 'Ettinger'. During the first four weeks of storage at 2°C, 4 °C, 6°C and 8°C the firmness decreased to 89.2N, 79.2N, 12.5N and 10.9N, respectively, indicating that the higher temperature accelerated the ripening process. These results are in accordance with those found by Mizrach *et al*. (2000).

Storage life of fruit is affected by storage temperature because higher temperature increases respiration rate, leading to fruit softening and at low-temperature storage metabolism is retarded by a reduction in respiration rate, ethylene production, color changes and softening (Perez *et al*., 2004). Arpaia *et al.* (1990) reported that cultivars Fuerte and Hass were successfully stored for 5-9 weeks without chilling injury at 5-7^0C in a controlled atmosphere (CA) storage of 2% oxygen and 10% carbon dioxide. In line with this Meir *et al.* (1995) found that a combination of 3% oxygen and 8% carbon dioxide extended shelf life of Hass avocado at 5^0C up to 9 weeks. This reduced ratio of oxygen in storage atmosphere resembles anaerobic respiration of fruit tissues producing acetaldehyde (AA) and ethanol. Accumulation of these endogenous respiration metabolites gives aroma to the fruit and inhibits ethylene production in plants. Application of exogenous acetaldehyde vapor to avocados before storage also inhibited fruit ripening by reducing ethylene production and activities of cell wall-depolymerizing enzymes and chilling injury symptoms at low temperature of 2^oC (Pesis *et al.*, 2002).

Researchers have shown when storage temperature decreases, growth of the mesophilic bacteria are reduced in shredded chicory salads (Nguyen-the and Carlin, 1994). Storage of fresh-cut fruits and vegetables at adequate refrigeration temperatures will limit pathogen growth to those that are psychrotrophic. Conversely, temperature abuse during storage will markedly reduce the lag and generation times, permitting development of mesophilic pathogens and more rapid growth of psychrotrophic pathogens.

2.4.2. Relative Humidity

Most fresh commodities require high relative humidity conditions during storage (Hofman *et al*., 2002a and Getinet *et al*., 2011). By increasing the relative humidity, the vapour pressure deficit is reduced, resulting in less water loss (Blakey, 2011). The negative effect of relative humidity on texture and appearance can be attributed to water loss (Paull, 1999). Adato and Gazit (1974) demonstrated that avocados at 10-20% relative humidity lost water three times faster than those stored at 90-95% relative humidity and 21°C to 22°C. The ripening process was also hastened by 3.3 days. However, Hofman and Jobin-Decor (1999) discovered that holding avocados at 60% relative humidity or less for four days resulted in an increase in the dry mass by 1.5% and reduced the days to ripen as compared to a 98% relative humidity. Storage conditions of mature avocados at 5°C and a relative humidity of 85-90% could result in a shelf life of two to three weeks (Perez *et al*., 2004).

2.4.3. Oxygen and Carbon dioxide

Meir *et al.* (1995) describes oxygen and carbon dioxide as having a synergistic role in inhibiting the ripening process of avocados through the increase in carbon dioxide and decrease in oxygen. Previous studies demonstrated that most successful atmospheres were created containing 2% oxygen and 10% carbon dioxide (Pesis *et al*., 2002). The study undertaken by Meir *et al*. (1995) showed that carbon dioxide and oxygen concentrations of 8% and 3%, respectively, yielded a storage time of nine weeks with marketable fruit and no chilling injury. ‘Fuerte’ exposed to 25% carbon dioxide for three days prior to storage at 5 °C for 28 days resulted in decreased disorders and lower levels of total phenols (Pesis *et al.*, 1994). Avocados subjected to excessively high carbon dioxide and too low oxygen concentrations induced exocarp and mesocarp injury Kader, (1997). Oxygen concentrations of less than 1% are likely to result in anaerobic respiration (Forero, 2007). Oxygen levels below 3% for prolonged periods are not recommended by Valle-Guadarrema *et al*. (2004). Lange and Kader (1995) showed that avocados stored in 40% carbon dioxide and 12.6% oxygen demonstrated increased respiration rates when compared to 20% carbon dioxide and 16.8% oxygen. Meir *et al*. (1995) related peel injury with low concentrations of oxygen and slower softening rates of avocados to be associated with higher carbon dioxide levels.

2.4.4. Ethylene Production and Sensitivity

Ethylene plays an important role in the ripening of avocado and its shelf life. Storage at low temperature delays ethylene production; however, storage at low temperatures can also cause chilling injury. Low storage temperatures generally range between 5^0C and 8^0C but could be reduced to as low as $2\text{-}8^0$C in order to reach a distant market (Flitsanov *et al.*, 2000). To prevent chilling injury in cold storage, ethylene absorption sachets are used to reduce levels of ethylene in the storage atmosphere (Adkins *et al.*,2005), or the avocados are treated with 1-methylcyclopropene (1-MCP), an inhibitor of ethylene action, before cold storing (Jeong *et al.*, 2003). Feng *et al.*(2000) measured the potency of 1-MCP in delaying ethylene-induced avocado ripening at various concentrations using cultivars Ettinger, Hass, Reed, and Fuerte. Mature avocados were treated for 24 hours at 22^0C with various concentrations of 1-MCP after ventilation and exposing to 300 ml/l ethylene for 24 hours. Subsequently, the author were stored in ethylene-free air at 22^0C and assessed for ethylene production, fruit firmness color, cellulase, and galacturonase activity during ripening. It was observed that 1-MCP inhibited ethylene-induced ripening at very low concentration of 30-70 nl/l and delayed ripening up to 13 days.

Ethylene has the potential to induce over-ripening, accelerate quality loss and increase susceptibility to pathogens during storage of fresh commodities (Martinez-Romero *et al*., 2007). The effect of ethylene on avocados can be identified as flesh softening, colour change and development of distinct aromas (Martinez-Romero *et al*., 2007). Zauberman and Fuchs (1973) found that treatment of avocados with ethylene at a storage temperature of 6°C contributed to accelerated respiration rates and softening. Fruit treated continuously with exogenous ethylene produced the least amount of ethylene compared to untreated fruit and those treated for 24 hours. It is suspected that the ethylene evolved is merely due to the diffusion of the exogenous ethylene that had initially been absorbed rather than production of ethylene by the fruit (Zauberman and Fuchs, 1973). Findings by the same authors prove that the removal of ethylene from storage atmospheres reduced the rate of softening. Ethylene formation in avocados have thus appeared to be independent of high temperatures, while at 40°C this process seems to be inhibited. Pesis *et al*. (2002) suggests absorbent sachets to remove ethylene from the packaging after five weeks storage at 5°C to reduce mesocarp discoloration and decay in ‘Hass’

2.4.5. Treatment with Calcium Chloride on Shelf life and Quality of Avocado fruits

The role of calcium chloride ($CaCl_2$) in the physiology of plant tissue is well established (Chaplin and Scott, 1980). Calcium is also important in the maintenance of membrane stability and permeability (Ferguson, 1984). Calcium acts as a cell wall firming agent and it controls the charge density in the wall thereby affecting ionic selectivity, which has a considerable effect not only on the cell wall bound components, but also on the metabolism of the cell (Demarty *et al*., 1984). Calcium is also known to inhibit the rate of respiration in avocado fruits by depressing the peak of ethylene production during climacteric stage and there is a positive correlation between lateness in ripening and high calcium levels (Eaks, 1985). This means the fruits remained firm, thus maintaining the keeping quality of avocado fruits (Meir *et al*., 1997).

John (1987) also reported addition of calcium improves rigidity of cell walls and obstructs enzymes such as polygalcturonase from

reaching their active sites, thereby retarding tissue softening and delaying ripening. Post harvest calcium application maintains cell turgor, membrane integrity, tissue firmness and delays membrane lipid catabolism thus extending storage life of fresh fruits (Chaplin and Scott, 1980).

Calcium chloride treatment resulted in a reduction of decay percentage. Postharvest rots frequently occur as a result of mechanical damage and they are caused by a wide array of microorganisms whereas grey mould is caused by *Botrytis cinerea*. This fungus is an aggressive pathogen that attacks fruits before harvest and is an important cause of loss in many commodities (Kader and Rolle, 2004). Crowe *et al.*(2005) reported that 100 ppm chlorine resulted in microbial reduction in total aerobes, yeast and mould counts in blueberries. Calcium chloride treatment resulted in low disease incidences and severity in avocado fruits. Calcium confers disease resistance since it maintains cell wall and membrane integrity. Additionally, high calcium concentrations in plant tissues increase resistance to disease attack and decay arising from wound invading microorganisms (Sams *et al*.,1993; Joyce *et al.*, 1997). Conway *et al.* (1987) reported the changes in firmness as an indication of a degradation of the apple cell walls and consequent reduction in fruit quality and Conway *et al.* (1987) further stated that the loss of firmness due to cell wall carbohydrate metabolism during storage has been associated with increased susceptibility to infection by fungal pathogens.

Pathmanaban *et al.* (1995) observed minimum water loss in Calcium treated fruits. The insufficient weight loss can lead to disorder such as mealiness and low temperature breakdown (Hatfield and Knee, 1988). Hatfield and Knee (1988), reported that as little as 5% loss in weight could cause shrivel in apples. Moreover, excessive shrinkages occur due to immaturity of the apple and days before storage.

2.4.5.1. Packaging films

The two most recognized avocado packaging techniques are modified atmosphere packaging (MAP) and controlled atmosphere storage (CAS) proven to extend avocado shelf life and retain quality (Berrios, 2002). Plastic materials that are primarily used for MAP of whole fruit and vegetables are polybutylene (PE), low density polyethylene, high density polyethylene, polypropylene, polyvinylchloride, polystyrene, ethylene vinyl acetate, ionomer, rubber hydrochloride (pliofilm) and polyvinylidine chloride (Workneh and Osthoff, 2010). The basic functions of food packaging are storage, preservation and protection for prolonged periods of time (Garlic *et al*., 2011).

Biodegradable films and coatings are becoming more apparent from an environmental perspective as they are easily recyclable (Aguilar-Mendez *et al*., 2008). The compositions of biodegradable films are essential in determining the postharvest behaviour of avocados and in the performance of the packaging itself. Gelatin-starch films and coatings are used on avocados with positive outcomes of firmer fruit pulps, skin color retention and lower weight loss. Higher starch concentrations and pH of the biodegradable film causes greater carbon dioxide permeability while lower levels of starch lead to higher film puncture strength. Gelatin and starch based films offer the benefit of being inexpensive and manufacturing is possible on a large scale (Aguilar-Mendez *et al*. 2008).

LDPE packages displayed suitable MAP conditions of low oxygen and high carbon dioxide in retaining avocado, papaya and mango freshness as compared to oriented PP and oriented PS films (Xiao and Kiyoto, 2001).

2.4.5.2. Modified Atmosphere Packaging

There exists a misconception that MAP and CAS is the same. However, MAP incorporates a lower degree of control over the concentration of gases as it depends on the interaction between the commodity and the packaging (De Reuck *et al*., 2010; Workneh and Osthoff, 2010). The aim of MAP is to create an optimal micro environment within the package specific to the avocado requirements to delay ripening and maintain the quality. According to Meir *et al.* (1997), Mangaraj *et al*. (2009), Sandhya (2010); Workneh and Osthoff (2010), equilibrium must be established between the avocado and the packaging based on the following factors: Maturity stage and respiration rate of the commodity, storage temperature, film surface area to fruit volume or weight ratio, and type of film (thickness and permeability to oxygen, carbon dioxide and water vapour).

Equilibrium is assumed to be established once the quantity of gas exchanged through the avocado is equivalent to that through the film (Mangaraj *et al*., 2009; De Reuck, 2010; Workneh and Osthoff, 2010). MAP is based on the principle of modifying the atmosphere within the package to lower oxygen concentrations and raise carbon dioxide concentration levels (Meir *et al*., 1997; Yahia and Gonzalez-Aguilar, 1998; Berrios, 2002; Hertog *et al*., 2003; Valle-Guadarrama *et al*, 2004; Mangaraj *et al*., 2009 and Workneh and Osthoff, 2010). This modified atmosphere suppresses respiration and ethylene formation, thereby promoting a longer avocado shelf life. Gas concentrations for MAP were found to be 2-6% oxygen and 3-10% carbon dioxide at 5°C and 7°C (Meir *et al*., 1997). This combination inhibits avocado softening and decreases the effect of chilling injury. Meir *et al*. (1997) investigated the effect of MAP on the storage of 'Hass'. Optimum results were found when storing 3.2 kg of the avocados in 30µm PE bags (40 x 70 cm) at 5ºC. The concentration of oxygen and carbon dioxide attained values of approximately 4% and 5%, respectively, at 5ºC and 7ºC. At 5ºC lower ethylene evolution was detected with firmer fruit. These concentrations are in accordance with those prescribed by Sandhya (2010) of 2-5% oxygen, 3-10% carbon dioxide and 85-95% nitrogen. Berrios (2002) recommends similar CAS and MAP conditions of 2-5% oxygen and 3-10% carbon dioxide at 5-13ºC for transportation and storage of avocados. Temperature variation of 7-14°C resulted in varying oxygen and carbon dioxide concentrations between 2-6% and 3-7%, respectively, (Meir *et al*., 1997). The avocados retained a good quality for up to seven weeks. Softening became evident within four weeks of storage as oxygen levels exceeded 9%.

Modification of the storage environment can be accomplished either through respiration of the commodity identified as natural or passive MAP or by intentionally introducing a gas mixture into the packaging identified as artificial or active MAP (Yahia and Gonzalez-Aguilar, 1998; Mangaraj *et al*., 2009; De Reuck *et al*., 2010 and Workneh and Osthoff, 2010). De Reuck (2010) stated that active MAP as opposed to a passive mode does not alter the gas composition at equilibrium, but rather the time taken for equilibrium to be established is shortened. The use of polymeric packaging material with appropriate pre-packaging, cooling and sanitation treatments is a major tool used to achieve adequate shelf-life for fresh-cut products (Schlimme and Rooney, 1994). The main objectives of fruit and vegetable packaging are shelf-life extension, maintenance of natural color, texture, flavor, and nutrients; reduction in moisture loss and subsequent wilting; limiting disease, infections and infestation; cushioning as a preventative measure against injury during handling and shipping; aid in processing, facilitating transport and help in labeling, advertisement, and marketing (FAO, 2005).

In general, methods and treatments that decrease aerobic respiration rate (without inducing anaerobic respiration), decrease microbial populations or retard microbial growth rate. These methods retard moisture loss from produce tissue, minimize mechanical damage to tissue, inhibit or retard enzyme-catalyzed softening and discoloration reactions, and delay ripening, senescence, and are employed to extend the shelf-life of fresh processed fruits and vegetables (Schlimme and Rooney, 1994). When fresh-cut products are packaged, the atmosphere within the package may be evacuated or flushed with a mixture of gases to establish more rapidly a desirable modified atmosphere. The correct combination of packaging material, produce weight, and gas composition within a package are critical components, which must be determined for each product to maintain product quality and extend product shelf-life (Gorny, 1996). Packaging cannot correct for unsanitary product handling, temperature abuse, or poor-quality raw materials. Proper sealing of bags is critical in maintaining product quality. Bags with imperfect seals will have higher oxygen concentrations and accelerate browning. Seal integrity as well as side and bottom seals on preformed bags should be checked often.

Flexible packs are plastic films characterized for having a high mechanical resistance to traction, perforation and low temperatures, in addition to presenting appropriate durability and sealability. Some of the main materials used for the elaboration of flexible packs are: High density polyethylene (HDPE), Polyvinyl chloride (PVC), Polypropylene and Polyamides (Cortez, 2004). Nevertheless, neither the type of packaging material nor the storage period affected texture, presentation (appearance), colour and odour of the product, Ormazabal (1999); Arze, (1993); Soliva-Fortuny, *et al.*, (2002); Sierra, (2004) and Nemesny, (2005) indicated that the physical appearance (presentation and color) of the Fourth Range products suffers minimal variations for until a period of 7 to 10 days, provided that the balance of the atmosphere inside the packaging is not affected. Ventilated Low-density Polyethylene (LDPE) linings have also being found to be beneficial, as this material maintains humidity, which results in less shrinkage during storage (Tharanathan *et al*., 2006). Polyethylene wrapping of $CaCl_2$ treated apple proved very useful for reducing weight loss and shriveling and retained consumer acceptability even after 60 days of storage (Hayat *et al*., 2005).

3. MATERIALS AND METHODS

3.1 Description of the study area

The avocado fruits were collected from Wondo Genet, Sidama zone of Southern Nations, Nationalities and People's Regional State (SNNPR) during 2012. It covers the area from some 15 km. south of the town of Shashemene, near the Wondo Genet College of Forestry. Wondo Genet is located at 7° 192N latitude and 38° 382E longitude with an altitude of 1780m.a.s.l. The site receives a mean annual rain fall of 1000 mm with minimum and maximum temperatures of 10 and 30°C respectively. The soil is sandy clay with an average pH of 7.2.

3.2 Experimental Treatments and design

The laboratory experiment consisted of two factors: the first factor was calcium chloride concentration with five levels (0%, 2%, 4%, 5% and 6%); the second factor was packaging material with four levels (High Density Polyethylene film, perforated Low Density Polyethylene film, and paper bag and control (unpacked)). The treatments combinations were arranged in factorial arrangement with Complete Randomized Design (CRD) with three replications. Each treatment had 66 fruits per replication. Hence, a total of 1320 fruits were kept under the experiment.

3.3 Experimental Procedure

Avocado fruits were purchased from El-Fora Malge Wondo Genet. Based on visual maturity determination, four to six avocado mother trees of good stand in the same orchard were selected and green mature avocado fruits were harvested with the aid of experienced personnel. Harvesting was carried out manually with maximum care to minimize mechanical damage. Fruits were transported to Hawassa University, food science laboratory using plastic boxes for physio-chemical analysis. Next, fruits were selected for uniformity of color, size, shape and freedom from defects. After removing field heat and cleaning, the avocado fruits were treated by dipping in 0%, 2%, 4%, 5% and 6%

sodium chloride solution which was freshly prepared using distilled water. Then surface of the fruits was dried out using cheese cloth and fruits were subdivided and packed as per treatments combinations. Finally, fruits were stored at ambient temperature conditions with three replications and the treatments were arranged on flat table. Data were recorded pertaining to the temperature and relative humidity of the storage room daily morning and afternoon until the shelf life of avocado was complet

3.4. Data collected

3.4.1. Physiological weight loss

Physiological weight loss (WL) was determined using the methods described by Mohammed *et al*.(1999). It was calculated from the initial weight of 110 treated avocado fruits taken from each treatment and were kept until the shelf life study was completed. Data for weight loss was collected at three days interval. The formula given below was used to calculate cumulative weight loss expressed as percentage for the respective treatments.

$$\%WL = \frac{Wi - Wf}{Wi} \times 100$$

Where, Wi = initial weight

Wf = final weight

WL = weight loss

3.4.2. Marketability

Procedure described by Mohammed *et al.* (1999) was employed to subjectively evaluate marketability of the fruits. The descriptive quality attributes were determined by observing the level of decay, color, surface defects, and shrivelling. A group consisting of 15 panelists (5 M.Sc. food science students, 5 staff workers and 5 M.Sc. horticulture students) was arranged to do assessment acceptability of fruits at three days interval and a total of 120 avocados fruits were subjected to the panelists for marketability analysis on each sampling day. A 1 to 5 rating scale, (with 1 = unusable, 2 = unsalable, 3 = fair, 4 = good, and 5 = excellent) was used to evaluate the fruit quality. Fruits receiving a rating of 3 and above were considered marketable, while those rated less than 3 were considered unmarketable. The number of marketable fruits was used as a measure to calculate the percentage of marketable fruits during storage. The percentage of marketable fruits during storage was calculated using the following formula

$$\text{Percentage of marketability} = \frac{\text{Number of marketable avocado fruits} \quad \text{X } 100}{\text{Total number of avocado fruits}}$$

3.4.3. Firmness

The firmness of fruits was measured using a digital penetrometer (model FT 011; 0-11lbs). Data were collected at three days interval and the firmness was measured from three position of the avocado fruit (anterior, middle and near to the basal part) without removing the seed. The values of the firmness are given in N.

3.4.4. Total soluble solids (TSS)

The total soluble solids (TSS) were determined after removing the peel, placenta and seed. Then the flesh of avocado halves from the fruit was homogenized in a laboratory blender using the juice. Firist the refractrometer standardizes using distilled water. Next, two drops of clear juice were placed on the prism of digital refractrometer and reading was taken by observing against light. Data on TSS were taken at three days interval and was recorded as ^{0}brix. The prism of the refractrometer was washed with distilled water between samples and dried with tissue paper before use.

3.4.5. pH value

Avocado juice was extracted every three days from the sample with a juice extractor at three days interval and it was used for the analysis of pH of avocado using a pH meter (Jenway model 3320).

3.4.6. Titratable acidity (TA)

Avocado juice was extracted from the sample with a juice extractor at three days interval and juice was used for the determination of titrable acidity (TA) following the methods described by Maul *et al.* (2000). TA was obtained by titrating 10 ml of Avocado juice to pH 8.2 with 0.1N NaOH. The titratable acidity was calculated using the following formula expressed as percent malic acid.

$$\text{TA (\%)} = \frac{\text{Titre x 0.1N Na OH x 0.0067}}{1000} \text{ X } 100$$

3.4.7. Dry matter content

The dry matter content of tomatoes was measured by placing the homogenised seedless samples in an oven at 105^0C for 24 h (AOAC, 2000). The dry matter of the sample was calculated using the formula:

% Dry matter = 100 - % moisture content

3.4.8. Percent of decay

The decay or rotting of the packed avocado fruits was determined by their visual observations. Decay percentage of avocado fruits was calculated as the number of decayed fruits divided by initial number of all fruits times 100.

$$\textbf{\% Decay} = \frac{\textbf{N° of decayed fruits}}{\textbf{Total nº of fruit}} \textbf{ X 100}$$

3.5 Statistical Analysis

Data were checked for meeting all ANOVA assumptions and subjected to Analysis of Variance using complete randomized design (CRD) using SAS statistical software version 9.2. Significant treatment means were separated using the Least Significant Difference (LSD) at 1% and 5% level of significance.

4. RESULT AND DISSICUSSION

4.1Percent weight loss

The results of the present study showed that there was no interaction effect of $CaCl_2$ treatment and packaging materials on percent weight loss of avocado fruits (Appendix 1). However, the calcium chloride concentration and packaging material had highly significant effect ($p<0.001$) on weight loss of fruits (Appendix 1). Fruits dipped in calcium chloride at different concentrations as well as packed with different packaging materials prevented weight loss in comparison with the control (Table 1). The weight loss varied from 1.46 to 13.46% during storage period of two weeks under ambient condition. The highest weight loss (13.46%) was recorded from avocado fruits in the control treatment (unpackaged), whereas the lowest weight loss was for fruits treated with high density polyethylene (HDPE). Similarly, treatment with 4-6% Calcium Chloride resulted in lower mean weight loss of fruits as compared to the untreated control which had maximum weight loss throughout the storage period (Table 1). The reduction in weight loss percentage might be due to the barrier of moisture such as polyethylene bags and the effect of calcium chloride in retarding ripening, ethylene production and respiration during storage and therefore less weight loss occurred in those treated fruits during storage.

In general, weight loss in avocado fruits progressively increased in all types of packaging materials and for all levels of calcium chloride treatments throughout the storage period. On day 6 of the storage period, weight loss of unpackaged (control) fruits was 5.06% which was significantly ($P < 0.001$) higher than weight loss of avocado fruits subjected to all other treatments on the same date. The HDPE packaged fruits had relatively lower weight loss compared to the weight loss in LDPE, and paper bag which in turn better than unpackaged (control) fruits which became totally unmarketable on the 12th days of storage.

The control fruits recorded weight loss which was morethan the acceptable weight loss threshold level (10%) up to day 9, whereas those avocado fruits packed with HDPE, LDPE, and paper bag approached the threshold on 12th day and passed the threshold level on the 15th day of storage period (Wills *et al*., 1989). About 10% physiological loss in weight is considered as an index of termination of shelf life (threshold level) of commodities (Pal *et al*., 1997).

Furthermore, the weight loss differences observed among the treatments of the present study might be due to differences in concentration of calcium chloride treatment and the variation in water vapor transfer rate of the packaging materials which could also play a significant role for the variation of the time to reach the threshold level. Calcium acts as a cell wall firming agent and it controls the charge density in the wall thereby affecting ionic selectivity, which has a considerable effect not only on the cell wall bound components, but also on the metabolism of the cell (Demarty *et al*., 1984). Calcium is also important in the maintenance of membrane stability and permeability (Roux and Slocum 1982; Ferguson, 1984). Moreover, it is known to inhibit the rate of respiration in avocado fruits by depressing the peak of ethylene production during climacteric stage and there is a positive correlation between lateness in ripening and high calcium levels (Eaks, 1985).

The reduction in weight loss percentage might be due to the barrier of moisture such as polyethylene bags and using of calcium chloride retard ripening, ethylene production and respiration during storage and therefore less weight loss occur in these treated avocado fruit during storage as compared to control. These results can be agreed with findings of Agar and Polate (1995) and Antunes *et al*. (2003) who observed less percent weight loss in apricot packaged in polyethylene bags. These results are also in line with the finding of Ibrahim (2005) who had used $CaCl_2$, polyethylene bags with $KMnO_4$ and observed a significant decrease of weight loss in apricots fruits. Mahajan and Dhatt (2004) also reported that pear fruits treated with $CaCl_2$ proved to be most effective in reducing weight loss compared to untreated fruits. The afore-mentioned results are in accordance with those recorded by Ashour (2000). The author found that dipping fruits in Ca solution at different concentration reduce apple weight losses percentages. Similar results were also presented by Tilahun and Kebede (2004). The relatively lower water vapor transmission rate of HDPE plastic may also contribute for the development of relatively higher humidity inside the package (Thompson, 2001; Farber *et al*., 2003; Mathooko, 2003).

Table 1: Effects of packaging and calcium chloride on physiological weight loss (%) of avocado over storage of 15 days at ambient condition

Treatments	**Storage period**				
	3	**6**	**9**	**12**	**15**
Packaging material					
HDPE	1.46^{d}	2.42^{d}	4.62^{d}	7.91^{c}	12.08^{c}
LDPE	2.47^{c}	3.34^{c}	5.53^{c}	8.90^{b}	13.04^{b}
PB	2.81^{b}	3.65^{b}	5.81^{b}	9.11^{b}	13.46^{a}
Control	3.9^{a}	5.06^{a}	7.27^{a}	10.58^{a}	-
LSD$_{(0.05)}$	0.16	0.20	0.20	0.23	0.17
CaCl$_2$ Concentration (%)					
0	2.98^{a}	3.9^{a}	6.09^{a}	9.48^{a}	9.98^{a}
2	2.85^{a}	3.85^{a}	6.03^{a}	9.39^{a}	9.69^{b}
4	2.52^{b}	3.48^{b}	5.68^{b}	8.96^{b}	9.65^{bc}
5	2.47^{b}	3.46^{b}	5.65^{b}	8.94^{b}	9.46^{cd}
6	2.46^{b}	3.40^{b}	5.59^{b}	8.85^{b}	9.45^{d}
LSD $_{(0.05)}$	0.18	0.23	0.22	0.25	0.19
CV $_{(\%)}$	8.38	7.80	4.79	3.42	2.47

Means in each column followed by similar letter(s) are not significantly different at $p<0.05$.

4.2. Percentage marketability

The result indicated that there was no interaction ($p>0.05$) effect of $CaCl_2$ treatment and packaging materials on percentage marketability of avocado fruits (Appendix 2). On the other hand, packaging material and calcium chloride treatment had significant ($p<0.05$) effect on the percentage marketability of avocado fruits (Appendix 2). Reduction in percentage marketability of avocado fruits packed by HDPE, LDPE, PB and control on day 3 was 0%, 0%, 6.77 and 13.07%, respectively. On day 6 and 9 reduction in percentage of marketability was highest in non package fruits (control) followed by PB packed avocado fruits. All unpacked fruits were totally unmarketable on day 12 while fruits packed with PB were unmarketable on day 15 of the storage period. Among the different concentrations of calcium chloride tested, avocado fruits treated with 6% $CaCl_2$ were found to be significantly superior as compared to control (untreated). These results are in line with those of previous studies of Moghadam and Eslani (2005) Robson *et al*. (1989) and Zora-Singh *et al*.(2000). This could be attributed to calcium chloride which might have conserved the qualities of fruits, prevented physiological disorders, reduced the rate of respiration, limited the solubilisation of pectin substances, maintaining the firmness and slowing down the ripening process (Magee *et al*., 2002). The termination of shelf life of stored avocado fruits was determined by shrivelling, over ripening, discoloration and mould growth. Shrivelling was predominant in the control fruits, paper bag packaged and polyethylene packaged fruits, respectively, while mould growth was more in HDPE plastics. Faster transpiration rate at relatively higher temperature may result in shrivelling of unpackaged fruits Polyethylene bags maintained high humidity reduced the loss of weight and consequently slowed down the drying process (De-Souza *et al*., 1999). Furthermore, higher respiration rate at higher temperature may lead to senescence because the stored food reserve which provides energy could be exhausted (Paull, 1993). On the other hand, condensation of water vapour, which may lead to the build-up of mould growth, may occur in the polyethylene bag due to the lower permeability of the film to water vapour (Thompson, 2001).

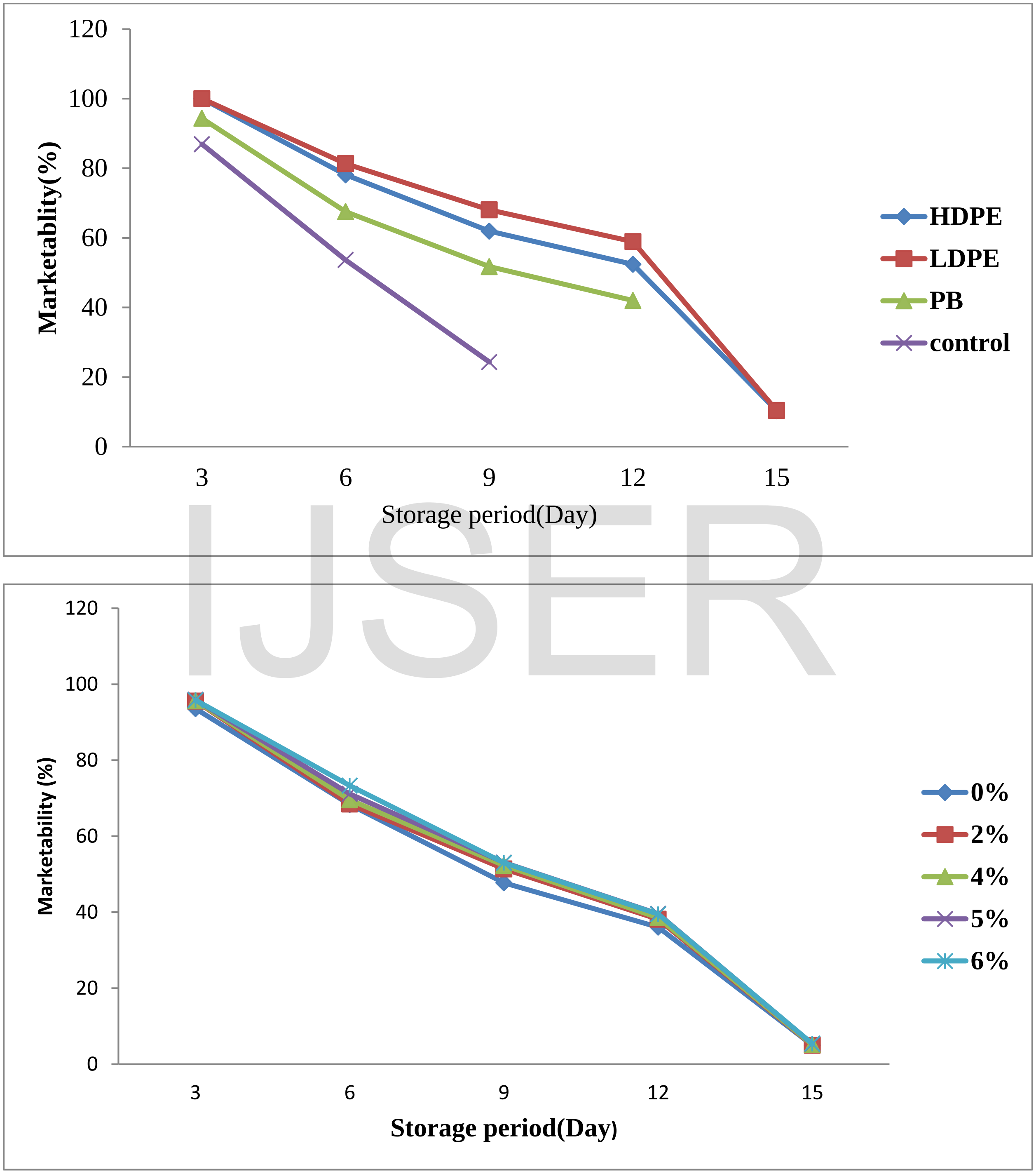

Figure 1: Effects of packaging and calcium chloride pre-treatment on marketability (%) of avocado over storage of 15 days at ambient condition

4.3. Dry matter of the pulp

The main effect of packaging material on mean dry matter content was highly significant ($P<0.001$); while the interaction effect was non-significant ($P>0.05$) (Appendix 7). Mean dry mater content of avocado fruits packed with HDPE and LDPE were found to be higher than with PB and control; similar trends were observed throughout the storage periods (Table 2). The maximum dry matter content values with HDPE (24.34%) and LDPE (23.61%) were on day 9 while with PB and control treatment maximum values were recorded on day 6 which declined thereafter (Table 2). Unpacked fruits and PB packed fruits showed statistically the same dry matter content on day 3, 6, 9 and 12. Likewise, HDPE and LDPE packaged avocado fruits recorded statistically similar dry matter content values on day 3,6,9, and 15 after storage (Table 2). Generally, the dry matter content of all packed and unpacked fruits were shown an increment of dry matter until day 9 and the decreases.

The different concentration of Calcium Chloride treatments had non-significant ($p>0.05$) effects on dry matter contents of avocado fruits in all sampling days (Table 2). There was no interaction ($p>0.05$) effect of $CaCl_2$ treatment and packaging materials on pulp dry mater content of avocado fruits (Table 2).

Table 2: Effects of packaging and calcium chloride on pulp dry matter (%) of avocado over storage of 15 days at ambient condition

Treatments	**Storage period (days)**				
	3	**6**	**9**	**12**	**15**
Packaging material					
HDPE	23.34^{a}	24.08^{a}	24.34^{a}	22.63^{a}	20.70^{a}
LDPE	22.76^{a}	22.67^{ab}	23.61^{a}	21.28^{b}	20.70^{a}
PB	21.50^{b}	22.23^{b}	21.75^{b}	20.10^{c}	19.10^{c}
Control	21.32^{b}	21.51^{b}	21.08^{b}	19.34^{c}	-
LSD(0.05)	0.21	0.42	0.76	1.05	0.71
$CaCl_2$ Concentration (%)					
0	22.35^{a}	22.50^{a}	22.45^{a}	21.83^{a}	14.82^{a}
2	21.95^{a}	24.03^{a}	22.92^{a}	20.60^{a}	15.34^{a}
4	22.36^{a}	22.87^{a}	23.00^{a}	20.71^{a}	15.18^{a}
5	21.61^{a}	22.67^{a}	22.85^{a}	20.64^{a}	15.10^{a}
6	22.89^{a}	21.86^{a}	22.25^{a}	21.05^{a}	15.17^{a}
LSD (0.05)	NS	NS	NS	NS	NS
CV (%)	7.37	8.52	7.36	6.88	6.39

Means in each column followed by similar letter(s) are not significantly different at p<0.05.

The lowest dry matter content of avocado fruits recorded on the unpacked once could be due to high respiration rate that might have used the stored dry matter as a substrate of respiration. In the HDPE packed fruits, the higher dry mater content could be due toreduced respiration and less moisture loss as compared to the unpacked once. In harmony to this, Dadzie and Orchard, (1997) reported that assessment of dry matter content is essential because, the high rate of respiration accompanied by water loss that occurs in fruits during ripening, particularly at the climacteric stage cause a net reduction in the proportion of the fruit dry matter. These two processes, rate of respiration and water loss could have been slowed down for avocado fruits packed with HDPE and LDPE bags packaging treatments.

4.4. Total soluble solids (TSS)

The changes in total soluble solids (TSS) content of avocado fruits during the 15 days of storage are displayed in Table 3. The result revealed that there was no interaction ($P>0.05$) effect of $CaCl_2$concentration and packaging material on total soluble solid of avocado fruits (Appendix 3). Packaging materials had significant ($p<0.05$) effect on total soluble solid of the fruits (Appendix 3). Highest total soluble solid was measured on unpacked fruits than all packed fruits but it was statistically the same with PB on day 12. On day 6 and 12 LDPE had higher total soluble solid than HDPE (Table 3). On day 3 and 12 fruits packed with PB had higher total soluble solid as compare to fruits packed with LDPE (Table 3). Total soluble solid values of fruits with packaging treatment varied from 7.24 on day 3 with HDPE to 10.16^{o}Brix in control on day 12. With packaged fruits,TSS on day 9 and decline thereafter.

Different concentration of calcium chloride had significant ($p<0.05$) effects on total soluble solid of avocado fruits (Table 3). On day 3, 12, and 15. The 6% $CaCl_2$ treated fruits had significantly higher total soluble solid compared to the 4%, 2% and 0% treated fruits. On day 6, 9, 12 and 15 fruits treated with 5% $CaCl_2$ also had shown significantly higher total soluble solid compared to the 0%. During all storage time, total soluble solid was statistically the same in fruits treated with 2%, 4% and 5% $Cacl_2$. Generally, total soluble solid of avocado fruits were increasing with increasing concentration of $CaCl_2$ (Table 3).

The above results show an initial rise and then a fall in the TSS of avocado fruits followed by fall in total soluble solid content were observed during the storage period. Increasing in total soluble solid content could be due to hydrolysis of starch into sugars as avocado fruit ripen. The decline of TSS of the fruits could be due to the use of the soluble sugars as respiration substrate which is promoted by higher temperature (Irtwenge, 2006). This result was in line with the finding of Stover and Simmonds (1987) who reported that the conversion of starch in to sugars was the most important change in ripening fruit.

Table 3: Effects of packaging and pre-treatment with Calcium Chloride on TSS (%) of avocado over storage of 15 days at ambient condition

Treatments	**Storage period (days)**				
	3	**6**	**9**	**12**	**15**
Packaging material					
HDPE	7.24^{c}	7.54^{c}	10.24^{c}	7.00^{c}	7.82^{a}
LDPE	7.36^{c}	7.78^{b}	10.40^{bc}	9.57^{b}	7.87^{a}
PB	7.54^{b}	7.78^{b}	10.48^{b}	10.15^{a}	7.89^{a}
Control	8.01^{a}	11.00^{a}	11.00^{a}	10.16^{a}	-
LSD(0.05)	0.16	0.17	0.20	0.25	0.20
$CaCl_2$ Concentration (%)					
0	7.44^{b}	7.69^{c}	10.39^{b}	8.96^{c}	5.71^{c}
2	7.48^{b}	7.80^{bc}	10.40^{b}	9.12^{bc}	5.84^{bc}
4	7.52^{b}	7.96^{ab}	10.54^{ab}	9.17^{bc}	5.85^{bc}
5	7.53^{ab}	7.97^{ab}	10.58^{ab}	9.33^{ab}	5.95^{ab}
6	7.71^{a}	8.06^{a}	10.73^{a}	9.51^{a}	6.11^{a}
LSD (0.05)	0.18	0.20	0.23	0.28	0.23
CV (%)	2.97	3.07	2.6	3.75	4.79

Means in each column followed by similar letter(s) are not significantly different at p<0.05.

Unpacked (control) avocado fruits had more TSS content compared with packed fruits may be due to accelerated ripening because of free access of the O_2 which increases respiration rates, resulting in faster conversion of starch to soluble sugars. Amaros *et al*.,(2008) also reported that packing of fruits in polyethylene films packages leads to the modification of atmosphere inside the bag. It reduces the concentration of O_2 and increased the concentration of CO_2 until a steady state is reached.

The higher preservation of total soluble solid contents in fruits treated with higher concentration of $CaCl_2$ might be due to delay in the ripening process in modified atmosphere having lower ethylene level and decrease in respiration or other metabolic processes during storage. These results are in line with reports by Arthey and Philip (2005) who had described that the higher retention of total soluble solid by calcium treated fruits is due to the slower alteration in cell wall structure and breakdown into simple sugars. These results are also in agreement with Su-Jinle *et al*.(2004) and Ibrahim (2005) who had used $CaCl_2$ and polyethylene packaging and obtained similar results.

4.5. pH

Highly significant (P<0.001) differences in pH value were observed for avocado fruits subjected to packaging; whereas non significant effect for $CaCl_2$ pre-treatments and the interaction effect did not significantly alter pH of the fruits during the storage period (Appendix 4). The mean pH value was highest in avocado fruits packed with HDPE, followed by fruits packed with LDPE, and least in the control. Similar trends were observed through the storage period (Table 4).

Avocado fruits kept in HDPE, LDPE plastic packaging and paper bag have exhibited a higher value of pH than fruits in the control treatments (non packaged fruits). This is in agreement with result of Salunkhe and Kadam (1995) who reported that unripe banana subjected to ripening in polyethylene bags at ambient temperature had significantly higher pH value indicating that the ripening process in these fruits was slowed down. The pH value of avocado fruits showed relatively lower value at the beginning, and when ripening advances, an increasing trend was observed. The same trend was observed for all types of packaging, even though the rate of change was different. This value was related to titratable acidity in which the higher the pH, the lower the titratable acidity (Gowen, 1995).

On day 3, 6, and 12 pH values of avocado fruits packaged in LDPE and PB did not vary statistically while control avocado fruits had the lowest pH values regardless of $CaCl_2$ concentration. Similar difference in pH value of fruits stored in the evaporative cooler and under ambient conditions was reported for Mango (Alye *et al*., 2007). This might be due to the high respiration rate of un packed fruits which is responsible for acid production of the fruits as confirmed by Wills *et al*. (1989). On the other hand, the higher pH values of packaged fruits could be explained by the relatively reduced respiration rate in the package than in the control fruits. Reduced O_2 and increased CO_2 which could be created as a result of produce respiration could delay the rate of respiration in the package (Mathooko, 2003).

The pH value of control avocado fruits was lower than the pH values of avocado fruits packaged in HDPE, LDPE and paper bag. This could be due to the use of acids as respiratory substrates increased at higher temperature and result in depletion of acid content of fruits stored at ambient condition as supported by Wills *et al*. (1989). Control fruits pH value was increased and reached maximum (5.56) on day 12 compared with the packaged ones and was terminated its shelf life on day 15 after storage whereas fruits packaged with paper bag, HDPE and LDPE bags attained their maximum pH value on day15 of storage period. On day 6, the pH values of avocado fruits were decreased with ripening of the fruits; however a tendency of increase in the pH value was observed from day 6 towards the end of the storage time. The decreasing trend followed by an increase in pH value of avocado with advance in storage time is in agreement with the previous findings by Camara *et al*. (1993) and Wills and Widjanarko (1995).

Table 4: Effects of packaging and pre-treatment with calcium chloride on pH (%) of avocado over storage of 15 days at ambient condition

Treatments	**Storage period (days)**				
	3	**6**	**9**	**12**	**15**
Packaging material					
HDPE	5.51^{a}	5.18^{a}	5.64^{a}	6.22^{a}	6.96^{a}
LDPE	5.32^{b}	5.07^{a}	5.42^{b}	6.02^{b}	6.83^{a}
PB	5.18^{bc}	4.89^{b}	5.30^{b}	5.90^{b}	6.27^{b}
Control	5.12^{c}	4.88^{b}	5.32^{b}	5.56^{c}	-
$LSD_{(0.05)}$	0.19	0.17	0.16	0.16	0.14
$CaCl_2$ Concentration (%)					
0	5.20^{a}	5.05^{a}	5.45^{a}	6.01^{a}	5.10^{a}
2	5.35^{a}	4.96^{a}	5.51^{a}	6.01^{a}	5.06^{a}
4	5.30^{a}	4.94^{a}	5.33^{a}	5.86^{a}	4.97^{a}
5	5.35^{a}	5.01^{a}	5.39^{a}	5.92^{a}	4.98^{a}
6	5.22^{a}	5.06^{a}	5.41^{a}	6.83^{a}	4.95^{a}
$LSD_{(0.05)}$	NS	NS	NS	NS	NS
CV (%)	3.83	4.68	4.21	3.88	4.01

Means in each column followed by similar letter(s) are not significantly different at p<0.05.

4.6. Titratable Acidity

The main effect of packaging material and calcium chloride pre-treatment on mean titratable acidity was highly significant (P<0.001); while the interaction effect was non-significant (P>0.05) (Appendix

5). On day 3, mean titratable acidity of avocado fruits packed with HDPE, LDPE, PB and control were 0.23, 0.21, 0.20, and 0.19%, respectively; similar trends were observed at other storage periods (Table 5). The maximum titratable acidity was observed in HDPE followed by LDPE and PB while the minimum was recoded in the control fruits.

Table 5: Effects of packaging and calcium chloride on TA% of avocado over storage of 15 days at ambient condition

Treatments	**Storage period (days)**				
	3	6	9	12	15
Packaging material					
HDPE	0.23^{a}	0.21^{a}	0.21^{a}	0.20^{a}	0.198^{a}
LDPE	0.21^{b}	0.20^{ab}	0.20^{ab}	0.19^{b}	0.191^{b}
PB	0.20^{b}	0.19^{b}	0.19^{b}	0.18^{b}	0.196^{a}
Control	0.20^{b}	0.20^{b}	0.19^{b}	0.19^{b}	-
LSD$_{(0.05)}$	0.01	0.01	0.01	0.00	0.00
$CaCl_2$ Concentration (%)					
0	0.19^{b}	0.19^{b}	0.19^{b}	0.18^{b}	0.144^{b}
2	0.20^{ab}	0.19^{b}	0.19^{b}	0.19^{b}	0.145^{ab}
4	0.20^{a}	0.20^{ab}	0.20^{ab}	0.19^{ab}	0.146^{ab}
5	0.21^{a}	0.21^{a}	0.20^{a}	0.19^{ab}	0.146^{a}
6	0.21^{a}	0.21^{a}	0.21^{a}	0.20^{a}	0.149^{a}
LSD $_{(0.05)}$	0.01	0.01	0.01	0.007	0.004
CV $_{(\%)}$	8.38	8.05	7.42	4.60	3.59

Means in each column followed by similar letter(s) are not significantly different at p<0.05.

Mean titratable acidity of avocado fruits treated with 6% calcium chloride pre-treatment recorded the highest TA% which reduced with concentration and recorded lowest value in the control; similar trends were observed at other storage periods (Table 5).

This study show that higher retention of titratable acidity in avocado fruits packaged in HDPE bags with the combination of 6% and 5% $CaCl_2$ whereas the lower concentration of $CaCl_2$ and LDPE and Paper bag were effective to retain the acidity. The retention of acidity with packaging and higher concentrations of $CaCl_2$ might be due to reduction in metabolic changes of organic acid into carbon dioxide and water. These results are in agreement with those of Ibrahim (2005) who have used the $CaCl_2$, $KMnO_4$ and showed higher retention of acidity in apricot during storage. Likewise results by Mohammad and Campbell (1993), in banana fruit stored in low density polyethylene bags with ethylene absorbent, showed higher retention of acidity. Agar and Polate (1995) also observed that the titratable acidity was higher in apricot stored in plastic bags.

4.7. Firmness

The main effect of packaging material and Calcium Chloride pre-treatment were highly significant ($P<0.001$) on fruit firmness stored for a storage period of 15 days at ambient condition; while interaction effect was non-significant ($P>0.05$) (Appendix 6). Fruit firmness of avocado with the packaging material varied in relation to storage period. At day 3, the mean firmness of avocado fruits packed with HDPE followed by LDPE were higher than those packaged with paper bag and the control which were 10.18, 9.30, 8.70, and 8.54N, respectively; the same trend was observed in the other days (Table 6). Similarly on day 3, fruit firmness varied significantly in relation to calcium chloride pre-treatment concentrations and ranged from the mean firmness of avocado fruits 8.56in the control to 9.78N in 6% Calcium Chloride treated fruits, respectively; the same trends were recorded on the remaining sampling days of storage (Table 6).

Fruits packaged in polyethylene bags were firmer than fruits packaged in paper bag and control fruits and fruits firmness in all packaging treatments declined with storage period under ambient condition. On day 15, fruits from the HDPE, LDPE and paper bag required a force of 1.34N, 1.31N and 1.29N respectively. Fruit firmness was decreased steadily during the 15 days of storage and this process was by far faster in the control fruits than in HDPE, LDPE, and paper bag packaged fruits. The softening process was also a little bit slower in paper bag packaged fruits as compared to control fruits. It has previously been reported by Salunkhe and Desai (1984) that controlled atmosphere storage or modified atmosphere packaging with high CO_2 inhibits the breakdown of peptic substances, which retains fruit texture and makes them firmer for a longer period. Firmer ripe fruit was considered as one of the benefits of controlled atmosphere storage or modified atmosphere packaging to reduce mechanical damage, avoid fungal infection and increase shelf life of fruits. This could be due to the reduced weight loss resulting from reduced respiration or lower enzyme activity for avocado fruits packaged in HDPE and LDPE bag packaging treatments.

Loss of firmness or softening during ripening has been associated with two or three processes. The first is the breakdown of starch to soluble sugar. The second is the breakdown of the cell walls or reduction in the middle lamella cohesion due to solubilisation of pectin substances. The third is the movement of water from the peel to the pulp during ripening due to the process of osmosis as supported by (Dadzei and Orchard, 1997). These results coincide with the finding of Agar and Polate (1995), Antunes *et al*.(2003) and Ibrahim (2005). This may be attributed to conversion of pectin substance to soluble forms by a series of physico-chemical changes that are caused by the action of pectin enzyme such as esterase and polygalacturonicdase (Weichmann,1987). Similar findings for papaya were reported by Lazan *et al*.(1993). The paper bag package also maintained firmness of avocado fruits better than the control. These effects of packaging materials may be attributed to their retardation effects on ripening and reduction of water loss (Manrique and Lajolo, 2004).

Table 6: Effects of packaging and calcium chloride on firmness (N) of avocado over storage of 15 days at ambient condition

Treatments	Storage period (days)				
	3	6	9	12	15
Packaging material					
HDPE	10.18^{a}	8.21^{a}	6.02^{a}	3.29^{a}	1.34^{a}
LDPE	9.30^{b}	7.85^{a}	5.58^{b}	3.09^{b}	1.31^{a}
PB	8.70^{c}	7.14^{b}	5.10^{c}	2.88^{c}	1.29^{a}
Control	8.54^{c}	6.28^{c}	4.19^{d}	2.52^{d}	-
$LSD_{(0.05)}$	0.43	0.38	0.30	0.19	0.06
Cacl$_2$ Concentration (%)					
0	8.56^{b}	6.72^{c}	4.72^{d}	2.80^{b}	0.95^{b}
2	8.88^{b}	6.83^{c}	5.03^{cd}	2.92^{ab}	0.96^{b}
4	9.03^{b}	7.38^{b}	5.23^{bc}	2.92^{ab}	0.97^{b}
5	9.63^{a}	7.80^{ab}	5.42^{ab}	3.00^{a}b	0.97^{b}
6	9.78^{a}	8.11^{a}	5.71^{a}	3.08^{a}	1.05^{a}
$LSD_{(0.05)}$	0.40	0.42	0.3	0.2	0.7
CV (%)	6.4	6.9	8.0	8.8	9.52

Means in each column followed by similar letter(s) are not significantly different at p<0.05.

Generally, there was softening of fruits as the storage time progressed which could be due to texture modification through degradation of polysaccharides such as pectin, cellulose and hemicelluloses that take place during ripening (Irtwange, 2006). It has been well established that texture changes in fruits are consequences of modifications by component polysaccharides that in turn give rise to disassembly of primary cell wall and middle lamella structures due to enzyme activity on carbohydrate polymers (Manrique and Lajolo, 2004). Hence, the differences in decrease of firmness of avocado fruits in the different treatments could partly be explained by differences in rate of respiration that affect solubility and depolymerisation of pectin during ripening (Lazan *et al*., 1995).

4.8. Decay

Interaction effects of packaging material and calcium chloride concentration had non significant ($p>0.05$) effect on decay percentage of avocado fruits (Appendix 8). Packaging materials had significant ($p<0.05$) effect on decay percentage (Appendix 8). On day 9 of the storage, all fruits packed with HDPE and LDPE were free of day. On this particular day of storage the highest (51.7%) and lowest (0%) decay percentages were recorded on unpacked fruits followed by PB packed fruits (42.2%) (Table 7). On day 12 of storage, the highest decay percentage was recorded on unpacked fruits. On this day all unpacked fruits were decayed (100%) and followed by PB packed fruits wherein about 87.13% of the fruits were decayed. The lowest percentage of decay was recorded on fruits packed with LDPE on day 12 and 15 storage time. On day 15 where the shelf life of fruits was ended, 100% of the fruits of PB and HDPE were decayed (Table 7). Irrespective of packaging, fruits treated with different concentration of $CaCl_2$ had no significant ($p>0.05$) effect on percentage of decay.

The above results showed that decay of 100% was observed for control fruits which could be due to faster respiration rate as a result of which the tissue became soft and created an entrance for decay causing microorganisms. Even though the plastic films were perforated equally, the permeability of HDPE bags to gases and water vapour was obviously lower than that of LDPE bags (Thompson, 2001).

Table 7: Effects of packaging and Calcium Chloride on decay (%) of avocado fruit over storage of 15 days under ambient condition

Treatments	**Storage period**		
	9	**12**	**15**
Packaging material			
HDPE	0	78.60^{c}	100.00^{a}
LDPE	0	75.06^{d}	99.13^{b}
PB	42.20^{b}	87.13^{b}	100.00^{a}
Control	51.73^{a}	100.00^{a}	-
LSD(0.05)	0.80	0.34	0.57
$CaCl_2$ Concentration (%)			
0	23.08^{a}	83.67^{a}	74.75^{a}
2	23.50^{a}	85.25^{a}	74.75^{a}
4	23.58^{a}	85.00^{a}	74.75^{a}
5	23.83^{a}	86.00^{a}	75.00^{a}
6	23.41^{a}	86.08^{a}	75.00^{a}
LSD (0.05)	NS	NS	NS
CV (%)	4.66	3.72	1.05

Means in each column followed by similar letter(s) are not significantly different at $p<0.05$.

Until day 6, none of the fruits became decayed and all the fruits were marketable without any decay in all types of packaging including control fruits. As a result the fruits subjected to HDPE, LDPE, and PB packaging remarkably had no sign of decay or diseases on the same date. This is might be due to the use packaging in polyethylene had created modified atmospheres and as a result the speed of changes were slow down during storage. These treatments helped in retention of overall acceptability and maintained the quality for a long period of avocado fruit. These results are in line with those of previous studies (Moghadam and Eslani, 2005; Robson *et al*., 1989;Zora-Singh *et al*., 2000).Whereas, these treatments have increased storage life of avocado fruit up to 15 days as compared to control which was un acceptable after 9th day of the storage. This is very encouraging news for those farmers producing avocado and may be recommended as coating material to increase the storage life of perishable fruits.

5. CONCLUSION AND RECOMMENDATIONS

Postharvest losses in fresh fruits and vegetables may occur anywhere from the point where fruit and vegetables have been harvested up to the point of consumption. Because avocado is naturally delicate, it is a target to many postharvest injuries and mechanical damages due to its thin skin and climacteric type of ripening nature. The fruit has a limited shelf life of less than a week under ambient tropical conditions. Hence, appropriate postharvest handling such as proper harvesting, packaging and handling practice, appropriate containers and storage facilities which minimize mechanical damage, moisture loss, slow down respiration rate and inhibit the development of decay causing pathogens are demanded for better protection and shelf life improvement of the fruit. Temperature is the most important determinant of fresh produce deterioration rate. An important supplement to proper temperature and relative humidity management is the use of modified atmosphere packaging.

With this background, research on the effect of different packaging materials and calcium chloride pre-treatment of different concentration at ambient temperature on the shelf life improvement of avocado was conducted at Hawassa University food science laboratory. The experiment was laid out with factorial combination of packaging and calcium chloride pre-treatment in complete randomized design with three replications. Avocado fruits were assessed for weight loss, marketability, firmness, total soluble solids, pH, titratable acidity, pulp dry matter, and percent decay during storage.

Weight loss (WL) of avocado fruits was significantly reduced in packages compared to the control under both storage conditions. The highest WL (10.58%) on day 12 was recorded in control (none packaged) fruits stored under ambient conditions whereas the lowest (1.46%) was for HDPE bag packaged fruits. Calcium chloride treated fruits and packaged with HDPE bag and LDPE and paper bag maintain their weight better than control fruits did throughout the storage period. After 9 days, all control fruits were unmarketable while those fruits packed with polyethylene bags and paper bag remained marketable till 12 days. Polyethylene packaging combined with calcium chloride improved the shelf life of avocado fruits up to 12 days. The HDPE followed by LDPE bag packaging maintained fruits firmness better than paper bag and control. The highest firmness value (10.18 N) was recorded for fruits packaged with HDPE while the lowest (2.52N) was for control fruits. Fruits packaged with polyethylene bags remained relatively firm up to 9 days of storage period compared to others which lost their firmness on the 6th day of storage.

During 6 to 9thdays of storage period, control (unpackaged) fruits stored under ambient condition had the highest total soluble solids (TSS), titratable acidity (TA), and total sugar content and the lowest pH value compared to the packaged ones. As the storage time advanced, packaged fruits had shown more TSS, TA, and lower pH values. Polyethylene bag and calcium chloride treated fruits were generally more effective compared to paper bag packaging materials and the control in maintaining the quality of the fruit. The total sugar content of control fruits were higher up to 15 days compared to the packaged ones. Finally it was concluded that calcium dips fruits retarded metabolism as indicated by the lower respiration rates of calcium treated samples.

Over all, packaging combined with calcium chloride treatment maintained the freshness and improved the shelf life of avocado fruits. Polyethylene bag packaging with 6% calcium chloride treatment were more effective compared to paper bag and the control fruits in maintaining the quality as well as prolonging shelf life and marketability of avocado fruits. Moreover, the current study indicated the need to undertake similar studies in the postharvest handling of avocado fruits with emphasis on:

- Testing other plastic types like polypropylene and polyvinylchloride for avocado packaging
- Integrating pre-packaging treatments with packaging

- The effect of packaging and calcium chloride treatment on microbial population and sensory qualities of avocado fruit and,
- Creating awareness about MAP and calcium chloride treatment so as to prolong shelf life, maintain the quality and reduce the losses of avocado fruit after harvest.

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7. Appendices

Appendix 1: mean squares for physiological weight loss (%) of avocado fruits as influenced as influenced with packaging material and calcium chloride concentration

		Storage period				
SV	Df	**3**	**6**	**9**	**12**	**15**
F-A	3	15.179^{***}	18.061^{***}	18.170^{***}	18.276^{***}	625.594^{***}
F-B	4	0.701^{***}	0.665^{***}	0.655^{***}	0.987^{***}	0.559^{***}
AXB	12	0.088^{ns}	0.132^{ns}	0.141^{ns}	0.179^{ns}	0.103^{ns}
Error	40	0.049	0.079	0.077	0.097	0.057
CV		8.38	7.8	4.7	3.42	2.47

*SV sources of variation, df degree of freedom; F-A, packaging; F-B, calcium chloride treatment; AXB, ns, non significant at $P < 0.05$; *, **, significant at $P < 0.01$, $P < 0.001$, respectively.*

.**Appendix 2:** mean squares for marketability (%) of avocado fruits as influenced as influenced with packaging material and calcium chloride concentration

		Storage period				
SV	Df	**3**	**6**	**9**	**12**	**15**
F-A	3	575.572^{***}	2336.733^{***}	5606.950^{***}	10533.083^{***}	537.350^{***}
F-B	4	11.475^{*}	2336.733***	5606.950***	10533.083***	537.350***

AXB	12	6.530^{ns}	26.275^{ns}	10.658^{ns}	6.791^{ns}	0.266^{ns}
Error	40	3.800	17.483	15.700	5.566	0.250
CV		2.045	5.95	7.69	6.14	9.64

*SV sources of variation, df degree of freedom; F-A, packaging; F-B, calcium chloride treatment; AXB, ns, non significant at $P < 0.05$; *, **, significant at $P < 0.01$, $P < 0.001$, respectively.*

Appendix 3: Mean squares for Total Soluble Solids contents (%) of avocado fruits as influenced as influenced with packaging material and calcium chloride concentration

		Storage period				
SV	Df	**3**	**6**	**9**	**12**	**15**
F-A	3	1.732***	2.632***	34.102***		
F-B	4	0.133*	0.268**	0.234*	0.528**	0.267*
AXB	12	0.100^{ns}	0.111^{ns}	0.132^{ns}	0.211^{ns}	0.120^{ns}
Error	40	0.050	0.059	0.079	0.119	0.079
CV		2.97	3.07	2.66	3.75	4.79

*SV sources of variation, df degree of freedom; F-A, packaging; F-B, calcium chloride treatment; AXB, ns, non significant at $P < 0.05$; *, **, significant at $P < 0.01$, $P < 0.001$, respectively.*

Appendix 4: Mean squares for pH (%) of avocado fruits as influenced by Packaging materials and calcium chloride treatment

		Storage period				
SV	Df	**3**	**6**	**9**	**12**	**15**
F-A	3	0.447^{***}	0.328^{**}	0.356^{***}	1.149^{***}	169.114^{***}
F-B	4	0.058^{ns}	0.034^{ns}	0.055^{ns}	0.085^{ns}	0.054^{ns}
AXB	12	0.026^{ns}	0.033^{ns}	0.038^{ns}	0.036^{ns}	0.036^{ns}
Error	40	0.041	0.055	0.053	0.040	0.040
CV		3.83	4.68	4.21	3.88	4.01

*SV sources of variation, df degree of freedom; F-A, packaging; F-B, calcium chloride treatment; AXB, ns, non significant at P < 0.05; *, **, significant at P < 0.01, P < 0.001, respectively.*

Appendix 5: Mean squares for titirable acidity (%) of avocado fruits as influenced by Packaging materials and calcium chloride treatment

		Storage period				
SV	Df	**3**	**6**	**9**	**12**	**15**
F-A	3	0.003^{***}	0.0008^{**}	0.0007^{**}	0.0007^{***}	0.143^{***}

F-B	4	0.0008^{*}	0.0009^{*}	0.0006^{*}	0.0007^{***}	0.0007^{***}
AXB	12	0.0005^{ns}	0.0002^{ns}	0.0003^{ns}	0.0001^{ns}	0.000^{ns}
Error	40	0.0002	0.0002	0.0002	0.0000	0.0000
CV		8 .36	8.05	7.42	4.60	3.59

*SV sources of variation, df degree of freedom; F-A, packaging; F-B, calcium chloride treatment; AXB, ns, non significant at P < 0.05; *, **, significant at P < 0.01, P < 0.001, respectively.*

Appendix 6: Mean squares for firmness (%) of avocado fruits as influenced byPackaging materials and calcium chloride treatment

Sv	df	Storage period				
		3	6	9	12	15
F-A	3	8.272^{***}	10.856^{***}	9.205^{***}	1.636^{***}	6.495^{***}
F-B	4	3.165^{***}	4.361^{***}	1.175^{***}	0.128^{ns}	0.019^{*}
AXB	12	0.0591^{ns}	0.0521^{ns}	0.0343^{ns}	0.107^{ns}	0.010^{ns}
Error	40	0.0345	0.066	0.0175	0.0175	0.008
Cv(%)		6.40	6.99	8.01	8.81	9.52

*SV sources of variation, df degree of freedom; F-A, packaging; F-B, calcium chloride treatment; AXB, ns, non significant at P < 0.05; *, **, significant at P < 0.01, P < 0.001, respectively.*

Appendix 7: Mean squares for dry matter (%) of avocado fruits as influenced by Packaging materials and calcium chloride treatment

Sv	df	Storage period				
		3	6	9	12	15
F-A	3	14.370**	17.542**	35.331***	30.897***	1533.637***
F-B	4	2.760^{ns}	2.952^{ns}	1.279^{ns}	0.833^{ns}	0.430^{ns}
AXB	12	0.497^{ns}	5.496^{ns}	3.074^{ns}	3.309^{ns}	1.807^{ns}
Error	40	2.688	3.717	2.797	2.056	0.935
Cv(%)		7.37	8.52	7.36	6.88	6.39

*SV sources of variation, df degree of freedom; F-A, packaging; F-B, calcium chloride treatment; AXB, ns, non significant at P < 0.05; *, **, significant at P < 0.01, P < 0.001, respectively.*

Appendix 8: Mean squares for decay (%) of avocado fruits as influenced by Packaging materials and calcium chloride treatment

Sv	df	Storage period		
		9	12	15
F-A	3	33769.448***	1485.111***	37286.150***
F-B	4	0.891^{ns}	11.441^{ns}	0.691^{ns}

AXB	12	0.313 ^{ns}	14.430 ^{ns}	0.691 ^{ns}
Error	40	1.200	10.083	0.616
Cv$_{(\%)}$		4.66	3.72	1.05

*SV sources of variation, df degree of freedom; F-A, packaging; F-B, calcium chloride treatment; AXB, ns, non significant at P < 0.05; *, **, significant at P < 0.01, P < 0.001, respectively.*

Appendix 9: Permeability characteristics of some plastic films with potential for use as MAP of fresh and lightly processed produce (Schlime and Rooney, 1994)

Film type	Transmission rate O$_2$^{1}	 Co$_2$^{1}	 H$_2$o^2
Low –density polyethylene (LDPE)	3900-13000	7700-77000	6-23.2
High- density polyethylene (HDPE)	52-4000	3900-10,000	4-10
Polypropylene (PP)	1300-6400	7700-21000	4-10.8
Polyvinylchloride (PVC)	620-2248	4263-8.138	>8

^{1}Expressed in terms of cm^{3}m^{-2}day^{-1} at 1 atm.

^{2}Expressed in terms of gm^{-2} day^{-1} at 37.8^{o}C and 90 percent RH

BIOGRAPHICAL SKETCH

Jemal Haji was born in Jaunary 1980 at Gedeb Hasasa in West Arsi, Ethiopia. He attended his elementary and junior school at Tijo Wakentra Elementary and Junior School from 1989-1997 and secondary school at Hasasa Senior Secondary School from 1998 to 2001. He joined Ambo College of Agriculture in 2002 and graduated with Diploma in General Agriculture in July 2004. He again re-joined Jimma University College of Agriculture and Veterinary Medicine in 2005 and graduate with Bsc in Horticulture August 2009. After graduation, he was employed by Agricultural and Rural Development Office as Senior Expert at Shashemenne and again he joined Hawassa University in October 2011 to pursue his postgraduate study in Horticulture.