EFFECT OF STAGE OF MATURITY AT HARVEST ON THE QUALITY OF SELECTED PAPAYA (*Carica Papaya* L.) FRUIT VARIETIES

M.SC.THESIS

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EFFECT OF STAGE OF MATURITY AT HARVEST ON THE QUALITY OF SELECTED PAPAYA (*Carica Papaya* L.) FRUIT VARIETIES

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Decision/suggestion of Department Graduate Council (DGC)

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Chairperson, DGC Signature Date

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Chairperson, CGS **Signature** **Date**

DEDICATION

I dedicate this thesis manuscript to my Mom and Dad who nursed me up with love and planted the seed of wisdom within me, from which my thirst for knowledge grew.

STATEMENT OF THE AUTHOR

I earnestly declare that this thesis is my work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at Jimma University and is deposited at the University's Library to be made available to borrowers under rules and regulations of university and the country. I gravely declare that this thesis is not submitted to any institution, bureau, anywhere for the award of any academic degree, diploma, or certificate.

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Place: Jimma, University

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BIOGRAPHICAL SKETCH

The author Bezawit seifu was born from her father Mr. Seifu Wolde Giorgis and Mother Mrs. Berhane Tefera in 1986 in Asella city, Arsi Zone of Oromia Regional state, Ethiopia. She attended her Elementary School in Asella Andenet Elementary and Junior school from 1993-1999. Then She attended her Secondary and preparatory education at Asella Comprehensive Secondary and Preparatory School from 2000-2003.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
AOAC	Association of Analytical Chemists
CSA	Central Statistical Authority
EHNRI	Ethiopian Health and Nutrition Research Institute
FAO	Food and Agriculture Organization
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
LSD	Least significant difference
MARC	Melkasa Agricultural Research center
OECD	Organization for the Economic Cooperation and Development
OECD	Organization for the economic cooperation and development
SAS	Statistical Analysis Software
TA	Titritable acidity
TCA	Trichloroacetic acid
TSS	Total soluble Solid

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ABSTRACT

Effect of Stage of Maturity at Harvest on the Quality of Selected Papaya (*Carica Papaya* L.) Fruit Varieties

Papaya (Carica papaya L.) is nutritionally important fruit crop grown in Ethiopia. The different varieties of Papaya (Carica papaya L.) harvested at different harvesting maturity stages exhibits different physicochemical properties and sensory quality results. The objective of this study was to make clear the effect of harvesting maturity stage on the quality of papaya fruit varieties. The changes in the quality were studied based on measured physicochemical, proximate composition and sensory quality of the fruit. The experiment was 6×4 factorial experiment arranged in CRD design with three replications. The first factor consisted of six different papaya varieties namely (MK-141, ML-121, KK-102, KK-103, CMF-078 and CMF-061) which were obtained from Melkasa Agricultural Research Centre horticulture orchard. While the second factor comprised of four harvesting maturity stages, HM1, HM2, HM3 and HM4, corresponding to Matured green, 1/4 yellow skin, 1/2yellow skin, and 3/4 yellow skin respectively. Fruits were stored at ambient temperature and data were collected on the different response variables and analyzed using SAS version 9.2 Software.The result of the study revealed that Variety and maturity at harvesting and their interaction effect had a significant effect on the physicochemical and sensory quality of papaya fruits. From the findings VarietyMK-141and ML-121 can be categorized as large fruits and variety CMF-061 and KK-102 as medium size fruits and variety KK-103 and variety CMF-078 as small sized fruits. The highest firmness was recorded from variety ML-121and the lowest from variety CMF-061. Firmness decreased with increase harvesting maturity stages. The TSS content was highest in variety KK-102 and lowest in variety ML-121. TSS increase with increase harvesting maturity stage. TA showed a decreasing trend as the storage time increased and the maximum was recorded from variety CMF-061while the minimum was from variety CMF-078.Ascorbicacid increase with increase harvesting maturity stages. On the other hand, the maximum ascorbic acid was recorded from variety KK-103 harvested at 3/4 yellow skin maturity stage whereas the lowest was recorded from variety ML-121 harvested at green mature stage. Beta-carotene content was highest in variety KK-102 harvested at 3/4 yellow skin maturity stage and the lowest was recorded from variety CMF-078 harvested at green mature stage. The protein and fat contents increased with increasing harvesting maturity stage from in all the six varieties while ash and fiber contents showed a decreasing trend. The sensory result showed the whole treatment combinations score resulted in overall acceptability score of 3 and above showing that fruits harvested at the four maturity stages had acceptable sensory quality. Finally, this research has helped to establish a relationship between variety and stage of maturity stage at harvest with papaya fruit quality. Farmers and other stakeholders are encouraged to harvest papaya fruits based on the intended purpose of the specific variety at different harvesting maturity stage and the distance of the nature of the market. Therefore, synchronizing during harvesting might be needed to have acceptable good quality fruits in the market and to satisfy the demands of the consumers of different categories. However, further studies are essential to assess the suitability of papaya fruits of different varieties harvested at various stages of maturity for production of a range of value added products.

1. INTRODUCTION

Papaya (*Carica papaya* L.) is a very wholesome fruit, and it is delight for the attractive pulp colour, flavour, succulence, and characteristic aroma (Desi and Wagh, 1995). The fruit is produced in about 60 countries, with the bulk of production occurring in developing countries (Salunkhe and Desai, 1984). Papaya is currently ranked third with 11.22 Mt, or 15.36 percent of the total tropical fruit production (Evans and Ballen, 2012). Global papaya production in 2010 was estimated at 11.22 Mt, growing at an annual rate of 4.35 percent between 2002 and 2010. Asia has been the leading papaya producing region, accounting for 52.55 percent of the global production between 2008 and 2010, followed by South America (23.09%), Africa (13.16%), Central America (9.56%), the Caribbean (1.38%), North America (0.14%), and Oceania (0.13%) (FAOSTAT, 2012). The world leading top ten papaya producing countries are India, Brazil, Nigeria, Indonesia, Mexico, Colombia, Ethiopia, Congo, Thailand, Guatemala (FAO, 2011).

It's a fast-growing tree-like herbaceous plant in the family Caricaceae. The Caricaceae was thought to comprise 31 species in three genera (namely *Carica, Jacaratia and Jarilla*) from tropical America and one genus, *Cylicomorpha*, from equatorial Africa. The origin of *Carica papaya* is in tropical America, it is likely that it originates from the lowlands of eastern Central America, from Mexico to Panama (Nakasone & Paull, 1998). Papaya is now grown in all tropical countries and many sub-tropical regions of the world (Samson, 1986; Paull, 1993).

Papaya is cultivated for its fruits, consumed both fresh and as a processed product worldwide (Sankat and Maharaj, 2001; Chonhenchob and Singh, 2005). A variety of products such as jam, jelly, nectars, ice cream, sherbet, yougurt, fruit leather and dried slices may also be made from the ripe fruit. Unripe papaya makes a good concoction of vegetable stew, salad or pickle. The milk latex of the unripe fruit, leaves and other parts of the plant contains papain, a proteolytic enzyme that digests proteins. Papain is used as a meat tenderizer and for medical and industrial purposes (Desi and Wagh, 1995; Sankat and Maharaj, 2001).

Papaya has been ranked one of the top for nutritional scores among 38 common fruits (Ming *et al*., 2008). It is also an excellent source of vitamin C and A (Nakasone & Paull, 1998). Nutritionally, the major components of papaya fruit pulp dry matter are carbohydrates. The total dietary fiber content of ripe fruit varies from 11.9 to 21.5g/100g,dry matter (Puwastien *et al*., 2000; Saxholt *et al*., 2008; USAD, 2009) crude protein range from 3.74 to 8.26g/100g dry matter (USDA, 2009). The fruit also recommended for low hypo caloric diets for its low calorie status (Lobo and Cano, 1998).

In addition, every part of the fruit is used in a variety medical purpose (Hewitt *et al*., 2000; Da Silva *et al*., 2010). Several experimental, clinical and epidemiologist studies have demonstrated that fruits and vegetables contain bioactive compounds with antioxidant and antimicrobial capacity, from different chemical classes such as phenolic compounds, carotenoids, vitamins(Gonzalez-Aguilar *et al.*, 2008).These were shown to help prevent cardiovascular diseases (Hu, 2003), atherosclerosis, decrease the risk of some types of cancers, among other health benefits(Yahia, 2009). Generally it has been argued by scientists that all parts of papaya, including seeds, roots, rinds, and fruits have positive effects on general health preventing diseases (Seigler *et al*., 2002).

In Ethiopia more than 61 thousand hectares of land is under fruit crops, papaya took up 4.44% (2,752.08ha), of the fruit production (CSA, 2012). An annual production of 4,793,360.64 quintals was estimated from fruit of which papaya, constituted 386,943.15 quintals (CSA, 2012). This shows that Ethiopia has great potential for production of papaya. In spite of the great potential for production of papaya in Ethiopia, the fruit industry has not been contributing much to the economy of the country. In addition there is no enough information on the existing physico chemical quality of the fruit on different harvesting maturity.

Many pre and postharvest quality factors influence the composition and quality of fruit. These includes genetic factors (selection of cultivars, rootstocks used for fruit species), pre harvest environmental factors (climatic condition and cultural practices), maturity at harvest, harvesting method, postharvest handling procedure, and processing and cooking methods (Lee and Kader, 2000).

Most important quality factors for tropical fruit growers, production managers, processors, and packers are fruit juice content, soluble solids and acid concentrations, soluble solids-acid ratio, fruit size, and color, showing that these characteristics may change regarding fruit species. The nutritional composition of a fruit at harvest can vary widely depending on cultivar, maturity, climate, soil type, and fertility (Lee and Kader, 2000; Paull, 1993; Samson, 1986). Maturity at harvest has a major impact on the quality and postharvest life potential of fruits. According to Dhatt and Mahajan, 2007 maturity at harvest plays an important role for postharvest life and eating quality, in particular for climacteric fruits where ripening is regulated by ethylene. It's also important for deciding when a given commodity should be harvested to provide some marketing flexibility and to ensure the attainment of acceptable eating quality to the consumer. Many people harvest papaya at the immature stage to avoid physiological damages but those fruits do not ripe correctly and give off flavors. The peel color and flesh color also do not develop well and skin gets damaged due to high latex exudation in immature fruits during harvesting. Those damages cause negative consumer preference in the market place.

As variation in production area or region, season, and cultivar may affect maturity indices and quality parameters , specific studies must be carried out on each species and variety. In addition the definition of the proper harvest time is essential, as fruit maturity at harvest greatly influences fruit market life potential and quality. Fruit producers have lost considerable market share mainly due to excessive early harvesting. A delayed harvest could lead to a better fruit organoleptic quality but also to faster softening and a shorter shelf-life. To date, there have been no enough report in the physical or chemical properties of different papaya varieties harvested on different maturity stage during postharvest ripening. The information on papaya postharvest quality can be of high value for growers, consumers, and distributors. So, the information on the physicochemical characteristics of fruit and chemical characteristics of pulp are important to assess the nutritional as well as sensory qualities of papaya. This study was initiated with the objective of studying the effect of stages of maturity at harvest on the quality of selected papaya fruit varieties so as to determine appropriate harvesting stages for the respective varieties.

2. LITERATURE REVIEW

2.1. The Papaya Crop

Papaya (*Carica papaya* L.) is an important fruit crop throughout the tropical and sub-tropical countries (Salunkhe and Desai, 1984). It is native to tropical America and is now cultivated in every countries (Paull, 1993). *Carica papaya* L, belongs to the family of Caricaceae. Among the other members of Caricaceae family, the cultivated papaya (*Carica papaya* L.) is the only one that belongs to *Carica* genus. Papaya is not a tree but an herbaceous succulent plant that possess self-supporting stems (Dick Gross, 2003). The plant is a soft-wooded perennial plant that lives for about 5-10 years (Chay-Prove *et al*., 2000). Papayas normally grow as single-stemmed trees with a crown of large palmate leaves emerging from the apex of the trunk. The soft, hollow, cylindrical trunk ranges from 30 cm diameter at the base to about 5 cm diameter at the crown and trees can reach 8-10 metres in height (Villegas, 1997).

Papaya is polygamous species and it is difficult to identify a plant whether it is male, female or hermaphrodite before flowering. The plants are male, hermaphrodite, or female (Bruce and Peter, 2008).The male trees are uncommon, but sometimes occur when homeowners collect their own seeds (Jari, 2009). Hermaphrodite trees (flowers with male and female parts) are the commercial standard, producing a pear shaped fruit (Jari, 2009). Papaya flowers can be grouped into three basic forms that reflect whole plant gender: female, male or bisexual (hermaphrodite). Broadly, there are two distinct types of *Carica papaya* plants: dioecious and gynodioecious (Chay-Prove *et al.,* 2000). Dioecious papayas have male and female flowers on separate trees. Gynodioecious papayas bare female flowers on some trees and bisexual (hermaphrodite) flowers on others. Papaya flowers are born on inflorescences which appear in the axils of the leaves (Chay-Prove *et al.,* 2000). Female flowers are held close against the stem as single flowers or in clusters of 2-3 (Chay-Prove *et al.,* 2000). Male flowers are smaller and more numerous and are born on 60-90 cm long pendulous inflorescences. Bisexual flowers are intermediate between the two unisexual forms (Nakasone & Paull, 1998). Fruit are ready to harvest five to six months after flowering, which occurs five to eight months after seed germination (Chay-Prove *et al*., 2000).

In accordance with (Paull and Duarte, 2011), papaya fruit is a fleshy berry, range in size from 7-30 cm long and 50 g to well over 10 kg, and it superficially resembles a melon, being spherical, pyriform, oval or elongated in shape. Fruit shape is a sex-linked character and ranges from spherical to ovoid in female flowers to long, cylindrical or pyriform (pear-shaped) in hermaphrodite flowers (Paull and Duarte, 2011). Fruit from female trees are spherical whereas the shape of fruit from bisexual trees is affected by environmental factors, particularly temperature, which modifies floral morphology during early development of the inflorescence (Nakasone & Paull, 1998). Depending on the cultivar, flesh thickness varies from 1.5 to 4 cm (Nakasone and Paull, 1998) and flesh colour may be pale yellowish to red (Villegas, 1997; Nakasone and Paull, 1998). Mature fruits contain numerous grey-black spherical seeds 5 mm in diameter (Villegas, 1997).

2.2. Importance of papaya fruit

Papaya is cultivated widely for consumption as a fresh fruit and for use in drinks, jams, candies and as dried and crystallized fruit (Villegas, 1997). The ripe fruit is consumed fresh for dessert and in fruit salad or processed. It is highly accepted worldwide and the demand for fresh papaya fruit is increasing (Lobo and Cano, 1998). The increase in consumption is due to high content of vitamin C and pro-vitamin A, which has a protective effect against cancer, and its low-calorie status that is recommended for low hypocaloric diets (Lobo and Cano, 1998). Papaya also has several industrial uses (El Moussaoui *et al*., 2001). Biochemically, its leaves and fruit are complex, producing several proteins and alkaloids with important pharmaceutical and industrial applications (El Moussaoui *et al*., 2001). The papaya fruit, as well as all other parts of the plant, contain a milky juice in which an active principle known as papain (Wilson, 1994). Papain used as a remedy in dyspepsia and kindred ailments, in addition it has been utilized for the clarification of beer. The juice has been in use on meat to make it tender (Wilson, 1994).

The seed is used for intestinal worms when chewed. The root is chewed and the juice swallowed for cough, bronchitis, and other respiratory diseases in addition the unripe fruit is used as a remedy for ulcer and impotence (Elizabeth, 1994). Fresh, green papaya leaf is an antiseptic, whilst the brown, dried papaya leaf is the best as a tonic and blood purifier (Atta, 1999). Chewing the seeds of ripe papaya fruit also helps to clear nasal congestion, (Elizabeth, 1994).

The tea, prepared with the green papaya leaf, promotes digestion and aids the in treatment of ailments such as chronic indigestion, overweight and obesity, arteriosclerosis, high blood pressure and weakening of the heart (Mantok, 2005).

2.3. Quality Attributes of Fresh Papaya Fruits

Quality, the degree of excellence or superiority, is a combination of attributes, properties, or characteristics that give each commodity value, in terms of its intended use (Kader and Rolle, 2004). In addition quality is defined as the absence of defects or degree of excellence and it includes appearance, color, shape, injuries, flavor, taste, aroma, nutritional value and being safe for the consumer (Abbott, 1999). Quality of produce encompasses sensory properties (appearance, texture, taste and aroma), nutritive values, chemical constituents, mechanical properties, functional properties and defects (Kader and Rolle, 2004). Shewfelt (1999) pointed out that quality is often defined from either a product orientation or a consumer orientation.

Due to a higher market demand for high quality products, the juice and pulp industries have been looking for fruits with better internal and external features (Cavalcante *et al*., 2012). This includes fruit length and width; fruit weight; pulp, seed and peel percentages per fruit; number of seeds per fruit; seed size and peel diameter; soluble solids (ºBrix); titratable acidity (%); vitamin C content (mg/100g of fresh fruit); pulp pH and soluble solids/titratable acidity ratio (Cavalcante *et al*., 2012).

The physical and chemical parameters of fruits are important indicators of their maturation and internal and external quality, decisive factors for accomplishment of market demands that have encouraged a lot of researches under different conditions overseas (Cavalcante *et al*., 2012). Paull and Duarte (2011) reported that fruit quality is related to some intrinsic characters (appearance, colour, acids, sugars, etc.) and since they change during handling. Inherently, the demand of fruit quality, physically and chemically talking, by industries, depends on fruit species and the product processed by each one of them (Cavalcante *et al*., 2012).

The relative importance given to a specific quality attribute varies in accordance with the commodity concerned and with the individual (producer, consumer, and handler) or market concerned with quality assessment (Kader and Rolle, 2004). To producers, high yields, good appearance, ease of harvest, and the ability to withstand long-distance shipping to markets are important quality attributes (Kader and Rolle, 2004). Appearance, firmness, and shelf-life are important from the point of view of wholesale and retail marketers. Consumers, on the other hand, judge the quality of fresh fruits, ornamentals, and vegetables on the basis of appearance (including ‘freshness’) at the time of initial purchase (Kader and Rolle, 2004). Subsequent purchases depend upon the consumer’s satisfaction in terms of flavor (eating) quality of the edible part of produce (Kader, 1999). According to (Kader and Rolle, 2004) the following is a description of the factors that contribute to the various qualities attributes of fresh produce.

Appearance (visual) quality factors these may include size, shape, color, gloss, and freedom from defects and decay. Defects can originate before harvest as a result of damage by insects, diseases, birds, and hail; chemical injuries; and various blemishes (such as scars, scabs, russeting, rind staining). Post-harvest defects may be morphological, physical, physiological, or pathological (Kader and Rolle, 2004).

Textural (feel) quality factors these include firmness, crispness, juiciness, mealiness, and toughness, depending on the commodity. Textural quality of horticultural crops is not only important for their eating and cooking quality but also for their shipping ability. Soft fruits cannot be shipped over long distances without substantial losses due to physical injuries. In many cases, the shipment of soft fruits necessitates that they be harvested at less than ideal maturity, from the flavor quality standpoint (Kader and Rolle, 2004).

Flavor (eating) quality factors include sweetness, sourness (acidity), astringency, bitterness, aroma, and off-flavors. Flavor quality involves perception of the tastes and aromas of many compounds. An objective analytical determination of critical components must be coupled with subjective evaluations by a taste panel to yield useful and meaningful information about the flavor quality of fresh fruits and vegetables. This approach can be used to define a minimum level of acceptability. In order to assess consumer preference for the flavor of a given commodity, large-scale testing by a representative sample of consumers is required (Kader and Rolle, 2004).

Nutritional quality factors of fresh fruits and vegetables play a significant role in human nutrition, especially as sources of vitamins (Vitamin C, Vitamin A, Vitamin B, thiamine, niacin), minerals and dietary fibre. Other constituents of fresh fruits and vegetables that may lower the risk of cancer and other diseases include carotenoids, flavonoids, isoflavones, phytosterols, and other phytochemicals (phytonutrients) (Kader and Rolle, 2004).

2.4. Factors affect Quality of Fruit

Many pre and postharvest quality factors influence the composition and quality of fruit (Lee and Kader, 2000). These include genetic factors (selection of cultivars, rootstocks used for fruit species), pre harvest environmental factors (climatic condition and cultural practices), and maturity at harvest, harvesting method, postharvest handling procedure, processing and cooking methods.

2.4.1. Pre Harvest Factors Affecting the Quality of Papaya

2.4.1.1. Genetic Factors

Quality factors are reported to be more or less genetically controlled (Scalzo and Mezzetti, 2010). Genotype has an important role in fruit quality, nutrient composition and postharvest life potential (Scalzo and Mezzetti, 2010). Internal factors such as genotype and fruit maturity stage affect the expression of genes, enzymes and metabolites (Carbone *et al*. 2009). Several studies have underlined the primary role of genetic control both of health and taste related compounds in fruits (Hernanz *et al*. 2007, Tulipani *et al*. 2008). Soluble solids content and acidity are determined by several factors such as cultivar (Byrne, 2003). Additionally, recent studies have analysed genotype x environment interactions affecting fruit quality and suggests environmental response to be genotype specific (Davik *et al*. 2006, Carbone *et al*. 2009).

Inconsistencies exist within cultivars in their quality traits (Lopez da Silva *et al*. 2007) which could be attributed to plant individual differences or to changes in the fruit quality during the harvest period. Cultivar selection is important because there are often differences in raw fruit compostion, durability, and response to processing (Kader, 2002). In many cases, fruit cultivars grown for fresh market sale will not be the optimal cultivars for processing (Kader, 2002). Cultivars range widely in shape, size, and color they also vary in their ability to achieve the desired phenotype under differing production conditions (Sanchez, 1996).

Wide variability is shown by the papayas grown in various countries (Desai and Wagh, 1995). The physicochemical parameters of papaya varieties differed from one another, which are supposed to be due to different genetic makeup of the variety and also because of the difference in their total fruit development and ripening period (Selvaraj *et al*., 1982; Desai and Wagh, 1995).

2.4.1.2. Climatic Conditions

Climatic factors, in particular temperature and light intensity, have great impact on the nutritional quality of fruits and vegetables. Consequently, the location of production and the season in which plants are grown can determine their ascorbic acid, carotene, riboflavin, thiamine, and flavonoid contents (Knee, 2002). In general, the lower the light intensity, the lower the ascorbic acid content of plant tissues; best quality papaya fruit, which is determined largely by sugar content, develops under full sunlight in the final four to five days to full ripeness on the tree (Samson, 1986).

2.4.1.3. Cultural Practices

Soil type, mulching, irrigation, and fertilization influence the water and nutrient supply to the plant, which can in turn affect the nutritional quality of the harvested plant part (Kader, 2002). The effects of mineral and elemental uptake from fertilizers by plants are, however, significant and variable. High calcium uptake in fruit has been shown to reduce respiration rates and ethylene production, delay ripening, increase firmness, and reduce the incidence of physiological disorders and decay, all of which result in increased shelf life (Kader and Rolle, 2004). High nitrogen content, on the other hand, is often associated with reduced shelf life due to increased susceptibility to mechanical damage, physiological disorders, and decay (Kader and Rolle, 2004; Kader, 2002).

2.4.1.4. Maturity stage at harvest

Maturity at harvest is the most important factors that determine storage life and final quality of fruit (Kader, 1999). It plays an important role for postharvest life and eating quality, in particular for climacteric fruits where ripening is regulated by ethylene (Dhatt and Mahajan, 2007). It’s also important for deciding when a given commodity should be harvested to provide some marketing flexibility and to ensure the attainment of acceptable eating quality to the consumer (Dhatt and Mahajan, 2007).

In postharvest physiology mature and ripe consider to be distinct terms for different stage of fruit development. Mature is having completed natural growth and development, for fruit, it is defined as the stage which will ensure proper completion of the ripening process. Most postharvest technologist consider that the definition should be, the stage at which a commodity has reached a sufficient stage of development that after harvesting and postharvest handling (including ripening, where required),its quality will be at least the minimum acceptable to the ultimate consumer (Kader,1999). Horticultural maturity is the stage of development at which a plant or plant part possesses the pre requisites for use by consumers for a particular purpose (Kader, 1999). A given commodity may be horticultural mature at any stage of development. A qualitative difference in the relationship between maturity and edibility distinguishes many fruits from vegetables. In many fruits, such as mature (but green) bananas, the eating quality at maturity will be far less than optimal. The fruit becomes edible only after proper ripening has taken place (Kader, 1999).

It is not easy to pinpoint the right harvest time for all fruit crops because it really depends on the individual commodity in particular conditions (Watada *et al*., 1984). All fruit, with a few exceptions (such as European pears, avocados, and bananas), reach their best eating quality when allowed to ripen on the tree or plant (Kader, 1999). However, some fruit are usually picked mature but unripe so that they can withstand the postharvest handling system when shipped long distance (Kader, 1999). Most currently used maturity indices are based on the compromise between those indices that would ensure the best eating quality to the consumer and those that provide the needed flexibility in marketing (Kader *et al*., 2002).

Harvesting papayas at proper level of maturity is essential for good quality produce (Kader and Rolle, 2004). Papaya fruits are generally picked when they exhibit a slight overall loss of green color, with some hint of yellow color at the blossom end (O'Hare, 1993). Moreover the latex consistence is changes from milky to watery indicating that the fruit is ready for harvest. Fruits harvested at an immature stage may not achieve normal ripening characteristics (Léchaudel and Joas, 2006). On the other hand, an overripe fruit may deteriorate quickly after harvest (Tefera *et* *al*., 2007). For long distance shipments the fruits are harvested at color-break stage (Kader, 1999). Immature-green fruits will not ripen after long-distance refrigerated transport (Kader, 1999). Many physical and chemical changes undergone by the developing fruit have been used as means of assigning the optimal picking dates for immediate consumptions or storage. It usually requires a combination of chemical and physical parameters, coupled with considerable experience (Salunkhe and Desai, 1984).

Fruits take more time for lesser mature fruits, which ripen at the same thermal regime. If fruits are harvested too early at green skin papaya, its consumption quality is not acceptable (Bron and Jacomino, 2006). Jha *et al*. (2006) reported that the storage longevity of fruits was closely related with the level of maturity at which the fruit was harvested. Maturity stage of fruit contributed to quality not only of fresh fruits but also of processing products as canned and canned puree fruit (Olaeta *et al*., 2003). Harvesting time also has influence on the fruit sensorial quality. Banana harvested at more advance maturity stages had better consumer acceptance (Ahmed *et al*., 2001).

2.4.1.5 Maturity Indices

Maturity indices give an indication of the stage of development or maturation of a crop and are determined on the basis of some characteristic known to change as the crop matures (Keerthi and Rosa, 2008). Both subjective and objective criteria are used for assessing the maturity indices of fruits.

Normally, several harvest indices are used to determine picking times such as size, skin and pulp color, acidity, sugar content, flesh firmness, and calendar day from bloom to harvest (Crane *et al.*, 2009). However, variation in maturity between fruits can be determined by different cultivars due to non-simultaneous flowering or the position of fruit attached on the tree (Johnson and Hofman, 2009). It is suggested that crop management before harvest to schedule optimum maturity may create advantages for postharvest applications. Harvest at different maturity stage altered fruit postharvest physiology and when effected at early stages, it reduced fruit quality but did not make its consumption unacceptable (Bron and Jacomino, 2006).

2.4.2. Postharvest factors that affect quality of papaya fruits

2.4.2.1. Respiration

A major metabolic process taking place in harvested produce or in any living plant product is respiration. Respiration is a process by which stored organic materials, carbohydrates, proteins, fats and other organic materials are broken down into simple end products, with a release of energy. 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 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 commodity's natural process of ripening, maturity and senescence (Desi and Wagh, 1995; Irtwange, 2006).

2.4.2.2. Ethylene production and sensitivity

Physiologically, papaya is a climacteric fruit with typical respiratory and ethylene production patterns during ripening. At the onset of ripening, respiration rises to a maximum (the climacteric peak) and subsequently declines slowly. The respiratory climacteric is just preceded with a similar pattern of increased ethylene production (Sankat and Maharaj, 2001; Bron and Jakomino, 2006).

2.4.2.3. Transpiration

Transpiration is the evaporation of water from plant tissues. It is a very important cause of produce deterioration, with severe consequences. Water loss is first, a loss of marketable weight and then adversely affects appearance (wilting and shriveling). Also, the textural quality is reduced by enhanced softening, loss of crispness and juiciness, followed by reduction in nutritional quality (Wills *et al*., 1989). The nature of the epidermal system of the commodity governs the regulation of water loss that is affected, as well as by environmental factors. Eventually, transpiration is a result of morphological and anatomical characteristics, surface-to-volume ratio, surface injuries and maturity stage on the one hand, and relative humidity, air movement and atmospheric pressure on the other (Wills *et al*., 1989; Irtwange, 2006).

2.5 Physiological and Chemical Changes during Fruit Ripening

Fruit ripening is an irreversible process engaging a series of physiological, biochemical, and organoleptic changes. It results in soft edible ripe fruit with desirable quality (Prasanna *et al.*, 2007). Biochemical changes in fruits after harvest still occurs. From consumers' point of view, some changes are expectable (color and flavor improvement), but other parameters (e.g. respiration, transpiration, etc.) can cause postharvest losses in fresh weight, appearance, texture and nutritional value (Lee *et al*., 1996).

In term of ripening mechanisms, fruits can be divided into two groups: climacteric fruits, in which ripening is accompanied by a peak in respiration and associated burst of ethylene, and non-climacteric fruits, in which respiration shows no sharp change and ethylene production remains at a very low level (Romero *et al*., 2003; Prasanna *et al.*, 2007). Climacteric fruits such as papaya, mango, banana quickly change their sweetness, aroma and softening during the ripening process. Furthermore, the decrease of chlorophyll content and the building up of carotenoid and phenolic compounds occur due to the differentiation of chloroplast into chromoplast in the ripening process of fruit (Chisari *et al*., 2009). Additionally, cell wall degradation and fruit softening are associated with ripening progression. Accordingly, the activity of polygalacturonase during fruit ripening correlates with cell wall disassembly, high activity of polyphenoloxidase and changes of color (Chisari *et al*., 2009).

An increase in aroma during fruit ripening is mainly caused by the mixture of volatile compounds such as ocimene and myrcene (Lizada, 1993). The taste development is marked by increase of gluconeogenesis, hydrolysis of polysaccharides, especially starch, and decrease of acidity (Lizada, 1993; Prasanna, 2007; Brecht and Yahia, 2009). Concentration of common sugar such as sucrose has been shown to be an important indicator for fruit quality assessment. The sugars and acids ratio could be influenced on tester's perception. Thus, consumer preference and interviews should be exploited to understand consumer's purchase behaviors. In immature fruit, sucrose is almost absent but it shows a significant increase during ripening and becomes the major carbohydrate constituent in the ripe fruit (Wang *et al*., 1996).

Changes in texture, peel, and pulp´s color, organic acid levels and synthesis of volatile compounds normally occur during detached papaya ripening, concurrently with the climacteric period (Paull, 1996). Papayas for commercial trade are harvested when the peel color approaches 1/4 yellow, about 110 d post-anthesis (dpa). At this stage, the pulp is still hard and its taste and flavor (similar to those of carrot) are unacceptable for consumption. There are many contradictions concerning soluble sugar synthesis and accumulation during ripening. Results from investigations done with papayas that ripened attached to the tree, receiving a constant supply of sucrose that originates from photosynthesis in the leaf, are quite different from those obtained in detached fruit. At the initial stages of papaya development, glucose is prevalent among the soluble sugars (Paull *et al*., 1997). With the changes of coloration in pulp and seeds, starting from the 110th dpa, there is a modification in the sugar profile at which time sucrose becomes the predominant sugar (Chan *et al*., 1979; Selvaraj *et al*., 1982). Chan *et al*. (1979) reported sucrose levels varying from 1.8% on the 110th dpa to 8.0% on the 135th dpa in attached fruits. On the other hand, a variation in detached fruits of about 2% in the total level of sugars between the 2nd and 22nd days after harvest (dah) was reported by (Hubbard *et al*., 1991). Because papayas have a low starch content at harvest time (about 0.1%), it would not be a sufficient carbon source for the increase in sucrose content and for post-harvest sweetening (Gomez *et al*., 1999).

2.6. Postharvest Biochemistry of Papaya

2.6.1. Enzyme Activity

During papaya fruit ripening, there is a good relationship between measures of ripening, respiration, ethylene production and skin color, and wall-degrading enzymatic activity. The enzymes reported include polygalacturonase (PG), pectin methylesterase (PME), xylanase and cellulase. There is a relationship between PG and xylanase and fruit softening (Paull *et al*., 1999). The peak in xylanase and PG activity occurs when the fruit has 40 to 60% skin yellowing (Paull, 1993).

In papaya, the rapid loss in firmness during ripening at ambient (25°C) temperature was associated closely with increase in activity of PG, PME and β-galactosidase, as well as depolimerisation of cell wall pectins. Modified atmosphere packaging and moderately low temperature treatments delayed as well as retarded firmness decrease, with the former being more effective than the later in retarding texture change, particularly when the fruit was stored below ambient (15°C) temperature (Lazan *et al*., 1993).

2.6.2. Carbohydrates

The largest quantitative change associated with ripening is usually the breakdown of carbohydrate polymers, especially the near total conversion of starch to sugars. This alters both the test and texture of the produce. The increase in sugar renders the fruit much sweeter and therefore, more acceptable (Wills *et al*., 1989). Carbohydrates are the most abundant biochemical constituents in fruits and represent about 80 to 50% of the total dry weight. They function as form of stored energy reserves and make up much of the structure framework of the cells (Kays, 1997). Ripe papaya contains 10 g of carbohydrate per 100 g of edible portion of raw fruit (Sankat and Maharaj, 2001). The principal carbohydrates in papaya fruit are sucrose, glucose and fructose. In the early stages of fruit development, glucose is the predominant sugar while at pre ripe and ripe stages, sucrose increases by two to five-fold, reaching higher level in the fruit than those of fructose and glucose. Total sugar content of the fruit showed positive correlation with fruit weight. The invert activity increases during ripening, causing the breakdown of sucrose to fructose and glucose (Sankat and Maharaj, 2001). Starch declines during fruit development to 0.1% dry weight in ripe papaya mesocarp tissue (Paull, 1993).

2.6.3. Organic Acids

Non-volatile organic acids form the major portion (80 to 90%) of total acidity in fruits. Citric acids and malic are the predominant acids, but tartaric, malonic, fumaric and succinic acids could also be present (Sankat and Maharaj, 2001). The major organic acids found in ripe papaya are citric acid, oxalic acid, and fumaric acid (Hernandez *et al*., 2009). There is slight increase in total acidity during ripening, which is believed to be associated with an increase in free galacturonic acid. Camara *et al*. (1993) reported an increase in total acidity of Solo papayas from 0.34 to 1.04 g100-1 g during 20 days of storage at ambient condition. The pH of papaya pulp ranges from 4.55 to 5.9, and the total titratable acidity (TA) calculated as citric acid is 0.2 to 1.4% (Senait *et al*., 1992; Camara *et al*., 1993). According to Paull (1993), 80% of the titrable acidity of papaya is made up of ascorbic acid which together with malic, citric and α-ketoglutaric acid make the total titrable acid. Total volatile acids contribute 8% of the total titratable acidity. Malic and citric acid are formed in about equal amounts; being ten times more abundant than α-ketoglutaric acid, malonic acid, fumaric acid and succinic acid. Ascorbic acid of papaya quadruples during fruit ripening. Bron and Jacomino (2006) reported that ascorbic acid (AA) content of papayas increased 20 to 30% during ripening, independent of the maturity stages at harvest. Wills and Widjanarko (1995) also noted that the AA content increased till before the fruit developed full yellow color.

2.6.4. Pigments

The progressive increase in softness of the tissue together with a change in color of the skin or flesh and a production of a wide spectrum of aroma compounds are some of the most easily recognizable changes that accompany ripening in climacteric fruit (Hobson, 1981). Many changes in pigments may occur during development, maturation and ripening on the plant. Some may continue after, or start only at harvest. These changes, which may be either desirable or undesirable, occur as a result of loss of chlorophyll, development of carotenoids (yellow, orange and red colors), and development of anthocyanins and other phenolic compounds (Irtwange, 2006).

During ripening, the color of the pulp of papaya fruit turns yellow or reddish. The caroteinoids (pro-vitamin A) content estimated as β-carotene, could increase to five to ten fold in yellow fleshed cultivars between the mature green stage and the full-ripe stage. In red-fleshed cultivars, however, the change in color is associated with a marked increase in lycopene content (Wills *et al*., 1989); lycopene was found to be absent in yellow fleshed fruit. On the other hand, it was found to be a major pigment, accounting for 61% of the total in ‘Solo’, 56% in ‘Formosa’ and 66% in ’Tailandia’ cultivars, while β-cryptoxanthin was the major pigment, representing 62% of the total caroteinoid content in a common cultivar of Brazil (Paull, 1993). On the other hand, skin chlorophyll declined to one-sixteenth of its content in ripe compared to immature fruit (Wills *et al*., 1989; Paull, 1993).

2.7. Nutritional compositions of papaya fruit

Papaya is a common man’s fruit, which is reasonably priced and has a high nutritive value. It is low in calories and rich in natural vitamins and minerals. *Carica papaya* is a source of carotenoides, vitamin C, thiamin, riboflavin, niacin, vitamin B-6 and vitamin K (Bari *et al*., 2006: Adetuyi *et al*., 2008; USDA, 2009). Papaya places first among the fruits for vitamin C, vitamin A, riboflavin, foliate, calcium, thiamine, iron, niacin, potassium and fiber. Papaya (100g) contains 9% of the Dietary Reference Intake (DRI) for Cu, 6-8% of the DRI for Mg, but less than 3% of the DRI for other minerals .The comparative low calories content (32Kcal/100g of ripe fruit) makes this a favorite fruit of obese people who are into weight reducing regime. Papaya has more carotene compared to other fruits such as apples, guavas, sitaphal and plantations, which help to prevent damage by free radicals. It is also used in salads, pies, sherbets, juice and confections. Papaya when consumed regularly will ensure a good supply of vitamin A, which are essential for good health especially for eyesight and can help to prevent early age blindness in children. It is also a good source of vitamin with amount varying between maturation stages and varieties (Bari *et al*., 2006, Hernandez *et al*., 2006; Wall, 2006).

Nutritionally, the major components of papaya fruit pulp dry matter are carbohydrates. The total dietary fiber content of ripe fruit varies from 11.9 to 21.5g/100g,dry matter (Puwastien *et al*., 2000, Saxholt *et al*., 2008; USDA, 2009) crude protein range from 3.74 to 8.26g/100g dry matter (USDA,2009).There are two main type of carbohydrate in papaya fruit, the cell wall polysaccharides and soluble sugars. At the early stage of fruit development, glucose is the main sugar but the sucrose content increases during ripening and can reach up to 80% of the total sugars (Paul, 1993 and OECD, 2010).The edible portion of the ripe papaya fruit contains both macro and micro minerals and these Na, K, Ca, Mg, P, Fe, Cu, Zn and Mn (OECD, 2010).

Papaya is good source of carotenoids, natural pigments responsible for the color of the fruit and related to biological functions or actions in humans such as pro-vitamin A activity, enhancement of the immune system, reduction of the risk of degenerative diseases such as cancer, cardiovascular diseases, macular degeneration, and cataracts (Cano *et al*., 1996; Chandrika *et al*., 2003). The red-fleshed papaya contain five beta carotene while the yellow fleshed contain only two beta carotene, β-cryptoxntain and zeta carotene (Chandrika *et al*., 2003). Only β -carotene, β-cryptoxanthin, and β-carotene5-6-epoxide, lycopene are precursors of pro-vitamin A. Some carotenoids are pro-vitamin A, and others are not. The consumption of papaya juice and fresh fruit being the best forms because they have higher bioavailability values and therefore can improve efficiently vitamin A.

3. MATERIALS AND METHODS

A study was conducted at Melkassa Agricultural Research Center (MARC) during 2012 and 2013 to evaluate the effect of varieties and harvesting time on the quality of papaya fruits. Materials used and the methods followed during the execution of the study are elaborated in this chapter.

3.1. Description of the Experimental Site

The experiment was carried out at MARC, Food Science laboratory in and the Horticulture division. MARC is located at 8^0 4'N latitude and $39^0$21'E longitude and 115 Km southeast of Addis Ababa. The experiment site is situated at an altitude of 1550 m.a.s.l. It is characterized by mean annual rainfall of 763 mm of which about 70% precipitates from June to September. Mean maximum and minimum temperature of the area are 28.4^0 C and 14.0^0 C, respectively (MARC, 2012). The proximate composition, Ascorbic acid and β-carotene analysis were carried out at Ethiopian Nutritional Health Analysis, Chemistry department laboratory.

3.2. Experimental Materials, Treatments and Design

Among twelve varieties of papaya that are being grown in the horticulture research plot six of them were purposively selected and used in the study. Based on secondary data and visual observation the six varieties were selected with the involvement of the horticulture staffs at MARC. The six varieties were developed at MARC thrugh controlled pollination and are currently proposed for national variety registration. Out of the six varieties used in this study five of them (i.e MK-141', 'ML-121', 'KK-102', 'KK-103', 'CMF-078') are hermaphrodite while variety CMF-061 is dioecious. The maturity stages at harvest were selected based on available literature and fruits were harvested based on visual observation of physical appearance, color and size (Basulto *et al*., 2009).

Table 1. Characteristics of papaya fruit Varieties used in the experiment

Varieties	Group	Flower	Fruit shape	Pulp color
MK-141	Solo	Hermaphrodite	Pyriform	Yellow
ML-121	Solo	Hermaphrodite	Pyriform	Yellow
KK-102	Solo	Hermaphrodite	Pyriform	Orange
KK-103	Solo	Hermaphrodite	Pyriform	Orange
CMF-078	Solo	Hermaphrodite	Pyriform	Orange
CMF-061	Solo	Dioecious	Round	Orange

The treatments consisted of 6*4 combination of six papaya varieties and four maturity stages were combined in a factorially arrangement in completely randomized design (CRD) with 3 replications. Therefore, there were 24 treatment combinations as indicated in (Appendix Table 2). Proximate composition; vitamin C; β-carotene and sensory analysis were done in duplicate.

3.3. Experimental Procedure

3.3.1. Sample preparation

After the time of maturity had been reached depending on the fruit size and color uniformity, sound selected papaya fruits uniform and free from mechanical damage or physiological and pathological disorders were harvested from MARC orchard in four groups. The fruit were picked by experienced personal of the research center for the appropriate laboratory determination. Harvesting was carried out manually with maximum care to minimize mechanical damage and it was performed early at the morning.

After harvesting the fruits were immediately transported to the laboratory. Fruits were selected for uniformity of color, size, shape and freedom from defects. Immediately after selection, fruits were washed with tap water containing 2% sodium hypochlorite solution to remove field heat, soil particles and to reduce microbial population. After surface drying with soft cloth, the fruits were transported to the food science laboratory of MARC. About 180 fruits for each harvesting maturity were collected on the same day. The fruits in each harvesting stage were then divided in to 24 treatment combinations and replicated three times having equal number of fruit (10fruits/treatment). Hence, a total of 720 fruits were kept at room temperature (23-25 ^{0}C). The treatments were arranged randomly selected and put in high density polyethylene box (crate).

Samples were taken from fresh fruits for the purpose of determining the Physicochemical parameters (Fruit weight, Length, Diameter, TA, and TSS). Dry samples were prepared for the proximate analysis from each treatment combination. The fruits were peeled to remove the skin and cut longitudinally to remove the seed using a sharp knife taking care of over peeling. The peeled papaya pulp was sliced in to 2-3cm and then poured on a drying tray followed by oven drying (Leicester, LE89 7FT, England) at a temperature of 58°C for 17-24h. Immediately after drying of the samples; dried samples were packed in non-transparent plastic container and stored under ambient temperature for one week until they undergo laboratory analysis of proximate composition, vitamin C (ascorbic acid), and β-carotene. The dried sample was finally milled with Cutting mill (SM2000/695upm, Germany) prior to analysis. For the sensory analysis fresh fruit samples were prepared after the fruits reached edible maturity (Firmness< 20N) (Bron and Jacomino, 2006).

3.4. Data Collection and Analysis Methods

Sample of two papaya fruits were randomly taken at a time from each treatment combination. Data collection was started immediately after harvesting and continued every other day interval for the chemical quality assessment. These determinations were repeated until the end of the storage day. The data for physical parameter were collected immediately after harvesting. For the sensory analysis data collection started after the fruit reach edible maturity stage. The data collection was conducted at Melekasa Agricultural Research Center (MARC) and Ethiopia Health and Nutrition Research Institute (EHNRI), in Food and Nutrition Research department, Addis Ababa Ethiopia. The separate analysis and determination procedures for every parameter are described below accordingly.

3.4.1. Physical parameters

3.4.1.1 Average Fruit Weight

Fruits weights were gravimetrically measured for each treatment. Weight of sample fruit was measured and recorded using precision scale (Sartorius GMBH Gottingen, Germany, Model LS200). It was calculated by dividing the sum of five fruits in each treatment combination divided by five.

3.4.1.2 Average Fruit Length and Diameter

The fruit length and diameter were determined for the fruit using digital caliper. The measurement was taken from the maximum length and diameter of the fruit. It was calculated by dividing the average of five fruit in each treatment combination.

3.4.1.3. Fruit Firmness

Fruits firmness from the different treatment was assessed using a texture analyzer (TA.XT. Plus, Stable Micro System Ltd., UK), equipped with a 2 mm diameter stainless steel probe. At least 3 measuring points were chosen close to the maximum fruit diameter. Test speed was set to 1.5 mm s^{-1}. The maximum force (N) registered for 10 mm penetration was expressed as peel firmness. The force required to penetrate was automatically recorded by software installed.

3.4.2. Chemical Quality Parameters

3.4.2.1. Determination of Total Soluble Solids

The total soluble solids (TSS) were determined after the peel and seeds were removed, and the flesh of papaya halve from the fruit was homogenized in a laboratory blender (New Harteford, Waring commercial, USA). Two drops of clear juice was placed on the prism of digital hand held refractrometer (Miscor R, Japan) with a range of 0 to 30°Brix and resolution of 0.2°Brix. Between samples the prism of the refractrometer was washed with distilled water and dried with tissue paper before use. The referactrometer was standardized against distilled water (0%TSS).

3.4.2.2. Determination of Titratable Acidity

For titratable acidity (TA) determination, papaya juice was extracted from the sample with a juice extractor (New Harteford, Waring commercial, USA). Clear juice was used for the analysis of TA as the methods described by Maul *et al*. (2000) using digital titration instrument (Jencons Digitrate, UK). Papaya juice (10ml) was diluted with 50ml distilled water and then five drop of phenolphthalein was added as an indicator. It was titrated with 0.1N NaOH until the indicator changed pink and then the volume of NaOH used was recorded. The TA, expressed as percent citric acid (1ml 0.1M NaOH is equivalent to 0.0064g citric acid) using the following formula.

$$Titratable\ acid(TA) = \frac{Titre\ x\ Acid\ factor\ x\ 100}{Juice\ (ml)} \quad \text{……….} \ (1)$$

Where: *Titre (Mill liter of sodium hydroxide utilized)*

Acid factor (0.0064g)

Juice (ml of amount of juice used for the titration)

3.4.1.3. Determination of Ascorbic Acid

The ascorbic acid content was determined by method described by Mohammed *et al*. (2009). About 5g of fruit sample weighed and extracted with 100ml of 6%TCA by mortar & pestle for 2-5 minute. The suspended solids removed by centrifuging for 30 min in a centrifuge. Then the sample transferred to a conical flask and 1-2 drops of saturated Bromine solution were added & aerated. Then to each 10ml aliquot 10ml of 2% thiourea was added. By using pipette from 10ml aliquot 4ml added into each of 3 test tubes. One tube set aside to serve as blank to each of the remaining tubes and 1ml of 2, 4-DNPH (2,4 Dinitrophenyl hydrazine) was added. The test tubes were put all in the water bath at 37^{0}C for 3 hour to facilitate reaction. Then the sample cooled in an ice bath for approximately 5 min to minimize the boiling risk of concentrated sulfuric acid. Five ml of 85%H_2SO_4 added slowly while the tubes were in an ice bath. Then 1ml of 2% DNPH was added to the blank and mixed. All tubes left at room temperature for 30 min. To prepare the standard first 100mg of AA weighed in the beaker and dissolved it with 5% metaphosphoric acid then the solution make up to 100ml with 5% metaphosphoric acid. Each ml of solution contains 20µg AA. To prepare 10,20,30,40 & 50 µg take 0.5,1, 1.5,2 & 2.5 ml in test tubes and dilute to 4 ml with 5%metaphosphoric acid. The absorbance of the standards, blank and test samples were read at 515 nm using a UV-visible spectrophotometer (DU-64 spectrophotometer, Beckman, USA).At the end the calculation was made using the following formula.

$$\mathbf{mg}\,\frac{\mathbf{AA}}{\mathbf{100g}} = \frac{[(\mathbf{As} - \mathbf{Ab}) * \mathbf{10}]}{[\mathbf{A10\mu g\,Std} - \mathbf{Ab}]} \ldots\ldots\ldots\ldots (2)$$

Where: A_s *Absorbance of samples*

A_b *Absorbance of blank*

$A_{10\,\mu g\,Std}$. *Absorbance of 10 µg AA standard*

3.4.2.4. Determination of β-Carotene

The beta carotene was determined by using spectrophotometer as the method described by (Rodriguez and Kimura, 2004). A homogenous 3g dried fruit sample was weighed and blended in a mortar and pestle with enough acetone. Then the sample was filtered into 100ml volumetric flask using filter paper. The residues were returned to the mortar and fresh acetone was added and macerates. The extraction and filtration were repeated until the residue was devoid of any color. Next 25ml of PE (petroleum ether) and the acetone extract were added in to the separator funnel. Then small quantity of distilled water was added and the samples were shacked well. The two phases were separated and the lower aqueous-acetone phase was discarded. The samples were washed 2-3 times with distilled water to remove residual acetone and water soluble components. Then the PE phase collected and dried with sodium sulphate. The PE phase transferred to drying flask and evaporate to dryness on a rotary evaporator. The residue dissolved in about 1ml of PE and the solution introduce into a chromatographic column. By eluting with PE the β-Carotene were collected in the flask then the β-Carotene goes through a column as a yellow pigment. Finally, the β-Carotene content of the samples were collected in measuring cylinder (100ml) and the absorbance were read using 1ml glass cuvates at 440nm by UV-visible spectrophotometer (DU-64 spectrophotometer, Beckman, USA). At the end the beta carotene content calculated using the following formula.

$$\boldsymbol{Amount}\ \left(\frac{\boldsymbol{\mu g}}{\boldsymbol{g}}\right) = \left(\frac{\boldsymbol{A} \times \boldsymbol{V}(\boldsymbol{ml}) \times \mathbf{10^4}}{\boldsymbol{A}_{\mathbf{1cm}}^{\mathbf{1\%}} \times \boldsymbol{W}}\right) \ldots\ldots\ldots\ldots (3)$$

Where:

A = Absorbance

$A_{1cm}^{1\%}$ *= Absorption coefficient of carotenoids in solvent used PE is 259*

V (ml) =Volume of the solution that gives an absorbance of A at a specified wavelength
W = weight of sample in gram

3.4.2.5. Proximate analysis

The proximate analyses of the fruit samples were determined as described by AOAC. All chemicals and reagents used in this experiment were analytical grade.

I. Determination of Crude Protein

The crude protein content was analyzed by micro-Kjeldahl method of nitrogen analysis according to AOAC (2000) method 979.09. To a digestion flask containing about 2g of sample, 5 ml of acid mixture (conc. Sulfuric acid and conc. Orthophosphoric acid) and about 3g of catalyst mixture (K_2SO_4 and Selenium) were added and digested (Kjeldahl flask KF250, Technical Glass Products, Inc., USA) at about 370^0 C until the solution becomes clear. To the digested sample, distilled water (30mL) was added and then, ammonia was distilled (KDN-102F, nitrogen analyzer distillation device) off after adding 25 ml of NaOH (40%) into receiving flask (25 ml of boric acid with 10 drops of indicator solution). Finally, the distillate was titrated with standardized 0.1N sulfuric acid to a reddish color. The crude protein content was estimated using equation 4:

$$Total\ nitrogen(\%) = \frac{(T - B)x\ N\ x14.007\ x\ 100}{w} \dots \dots \dots \dots (4)$$

Where:
T-Volume in ml of the standard acid solution used in the titration for the test material
B - Volume in ml of the standard acid solution used in the titration for the blank determination
N - Normality of standard sulfuric acid
W - Weight in grams of the test material

Crude protein (percent per weight) = 6.25 * total nitrogen

Π Determination of Crude Fat

Crude fat was determined by Soxohlet fat extraction according AOAC (2012) method 2003.06. A clean and dried thimble containing about 2g of dried sample and covered with fat free cotton at the bottom and top was placed in the extraction chamber and transferred in to extraction apparatus. The beaker was rinsed for several times with the solvent diethyl ether. The sample contained in the thimble was extracted with the solvent diethyl ether in a Soxhlet extraction apparatus (SZC-C fat determinate, China) for 6-8 hr at a condensation rate of at least 3-6 drops per second. At the completion of the extraction, the extract was transferred from the extraction flask into a pre-weighted evaporating small beaker (150-250ml) with several rinsing with the solvent. The diethyl ether was evaporated until no odor of its detected. The beaker and contents was dried in the oven for 30 minutes at 102$^oC \pm 2^oC$ to remove moisture and cooled in the desiccators. Finally, the beaker and contents was weighed and crude fat content was determined as indicated in equation 5:

$$Crude\ fat(\%) = \frac{W2 - W1}{Weight\ of\ sample}\ x\ 100\% \ldots\ldots\ldots\ldots (5)$$

Where:

W_1 = *Weight of extraction flask before extraction*

W_2 = *Weight of extraction flask after extraction.*

III. Determination of Crude Fiber

The crude fiber was determined by the non-enzymatic gravimetric according to AOAC (2000) method 920.169. About 1.5 g of sample was weighed in each of 600 ml beaker. A 200 ml of 1.25% sulfuric acid solution was added to each beaker and allowed to boil for 30 min by rotating and stirring periodically. During boiling the level was kept constant by addition of hot distilled water. After 30 min, 20 ml of 28% potassium hydroxide solution was added in to each beaker and again allowed to boil for another 30 min. The level was still kept constant by addition of hot distilled water. The solution in each beaker was then filtered through crucibles containing sand by placing each of them on Buchner funnel fitted with No.9 rubber stopper. During filtration the sample was washed with hot distilled water. The final residue was washed with 1% sulphuric acid solution, hot distilled water, 1% sodium hydroxide solution and finally with acetone. Each of the crucibles with their contents was dried for 2 hr at 130^{0}C and cooled in desiccators and weighed (M_1). Then again they were ashed for 30 min at 550^{0}C in furnace (Gallenkamp, Model FSL 340-0100, UK) and were cooled in desiccators. Finally the mass of each crucible was weighed (M_2) to subtract ash from fiber. The crude fiber was calculated from the equation:

$$Crude\ fiber\ \% = \frac{M1 - M2}{weight\ of\ sample}\ x\ 100 \ldots\ldots\ldots (6)$$

Where,

M_1 = mass of crucible and residue before ignition

M_2 = mass of crucible and residue after ignition

V. Total Ash Determination

The ash content was determined by AOAC (2000) method 923.03. A porcelain dish was placed in muffle furnace for 30 minutes prior to cooling in desiccators for an hour. The mass of dried porcelain dish was measured by analytical balance (ABJ220-4M, WB1151070, Australia) (M_1). A dry porcelain dish containing 5g sample was weighed (M_2) .The sample dried at 120^{o}C for 1hr in drying oven. Then it removed from the drying oven and carbonizes by blue flame of Bunsen burner by placing the sample dish on wire gauze. The sample was then carbonizes by blue flame of Bunsen burner (Model SX-5-12, China) at about 550^{o}C until free from carbon and the residues appear grayish white (about 8 hours). The sample was removed from the furnace and placed in the desiccators followed by weighing the mass (M_3).

$$Total\ ash(\%) = \left(\frac{M3 - M1}{M2 - M1}\right) x100 \ldots\ldots\ldots\ldots (7)$$

Where,

M 1 =Weight of the dish

M 2 =Weight of fresh sample and dish

M 3 =Weight of ash and dish

3.4.3 Sensory evaluation

The organoleptic character (i.e., color, flavor, taste and overall acceptability) made on the fresh fruit. All papaya fruit samples harvested at four harvesting maturity (Matured green, ¼ yellow skin%, >1/2% yellow skin, 3/4 yellow skin) and ripened at ambient temperature for four days were subjected to sensory evaluation. A hedonic test was carried using 50 volunteers selected among the staff working in the Melkassa Agricultural Research (MARC). Testing was performed in the food science laboratory under fluorescent lighting. Each papaya was peeled and its seed was separated cut into smaller pieces. Then the fresh papaya fruit samples were served in small plastic tray labeled with random three-digit codes. The order of presentation of the tray was at random for each panelist. Panelists were asked to taste the sample and evaluate it for each attribute in a specific scale provided. Distilled water was provided to rinse the mouth between evaluations. Then the score of all judges for each sample were summed up and divided by the number of panelists to find the average. The hedonic scale comprised scores of 1 to 5, where 1= dislike; 2= slightly dislike 3= neither like nor dislike 4= slightly like and 5 = like). The sensory attributes evaluated color, flavor, taste, and overall acceptance.

3.4 Data Analysis (Statistical Analysis)

Analysis of variance was done using the General linear Model procedure of statistical Analysis system (SAS; 2010) version 9.2 to determine the significant of variation among samples. Mean comparison was undertaken with Least Significant Difference (LSD) at required levels of probability (p=0.05). The treatment means showing significant difference were separated by using the small letters from a to z.

4. RESULTS AND DISCUSSION

4.1 Physical Quality of Papaya (*Carica papaya L*) Varieties

4.1.1. Average Weight of single fruit

Fruit characteristics related to single fruit weight, length and diameter were studied and tried to discuss as follow. The main effect of the varieties showed a significant ($p < 0.05$) difference on average single fruit weight (Appendix Table 3). However, the interaction effect between varieties and harvesting maturity on average weight of single fruit were found to be non-significant ($P>0.05$). The different harvesting maturity viz. matured green, 1/4 yellow, 1/2 yellow skin, and 3/4 yellow skin not significantly affect ($P > 0.05$) the average weight of single fruit. The fruits weight was varied among the six varieties and the range was from 289.89-927.80g (Figure 1). The variety MK-141 gave the maximum fruit weight (927.80g) followed by variety ML-121 (902.65g), variety CMF-061(649.69g), KK-102 (545.83g), and KK-103(335.28g); while it was minimum in CMF-078 (289.89g)..There is (68.75%) weight difference between the maximum and the minimum weight fruit. This weight difference may have influence on the end use of the fruit and in the kind of packaging material we are going to use.

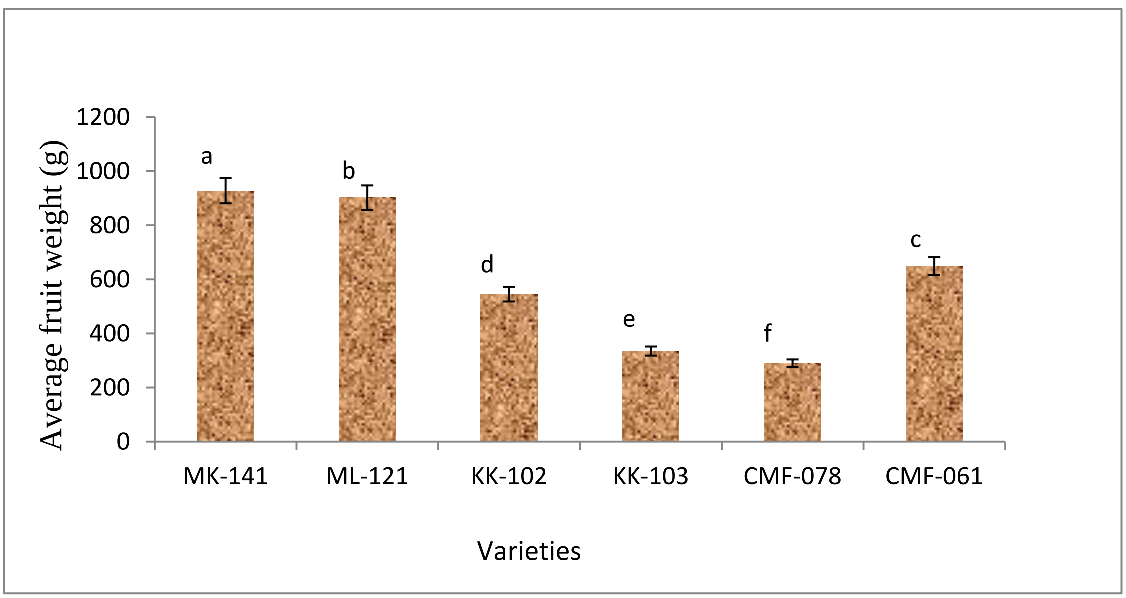

Figure 1. Effect of variety on the average single fruit weight

Bars capped with different letter are significantly different at (p<0.05).

The variation in weight could be due to intrinsic genetic difference between the different varieties. It was reported that the fruits of the four papaya varieties differed respect to their physical characteristics and the weight of the papaya varieties varied from 0.415 to 1740.00 g (Zaman *et al*., 2006). In addition the result found in this study supported by (Akhter *et al*., 2012) that the range of fruit weight was found from 260.1 g to 1150.0 g. This finding further supported by (OECD, 2003) that the fruits vary in mass from about 250 to 3000g.

4.1.2 Average length and diameter of papaya fruit

There was a highly significant difference among the six varieties in respect of length of fruit. The main effect of the varieties showed a significant ($p<0.05$) difference on length of single fruit (Appendix Table 4). However, the interaction effect among varieties and harvesting maturity on average length of single fruit were found to be non-significant. In addition the main effect of different maturity stages at harvest did not affect the average length of individual fruits. The longest fruit was that of variety MK-141 (22.61cm), followed by ML-121(20.20cm), KK-102(15.34cm), CMF-061(13.70 cm) and KK-103(13.43cm) while the shortest fruit (11.14cm) was measured from variety CMF-078 (Figure 2).

This finding is supported by Zaman *et al*. (2006) who reported that fruit length of the different papaya varieties varied from 0.22 to 20.0 cm. In addition Akhter *et al*. (2012) reported a significant differences among the 20 germplasms in respect of length of fruit and the longest fruit (24.50 cm) and the shortest fruit was (5.483 cm).This finding is also in persistent with Shattir and Abu-Bakr (2010) who reported that the female fruits were shorter and wider, compared to the hermaphrodite fruits. At physiological maturity, the hermaphrodite fruits were 20.3% longer than female fruits. Schweiggert *et al*. (2011) investigated the maximum fruit length during carotenoid accumulation in red fleshed hermaphrodite papaya fruit and it was found to be (22.3±2.2 cm).

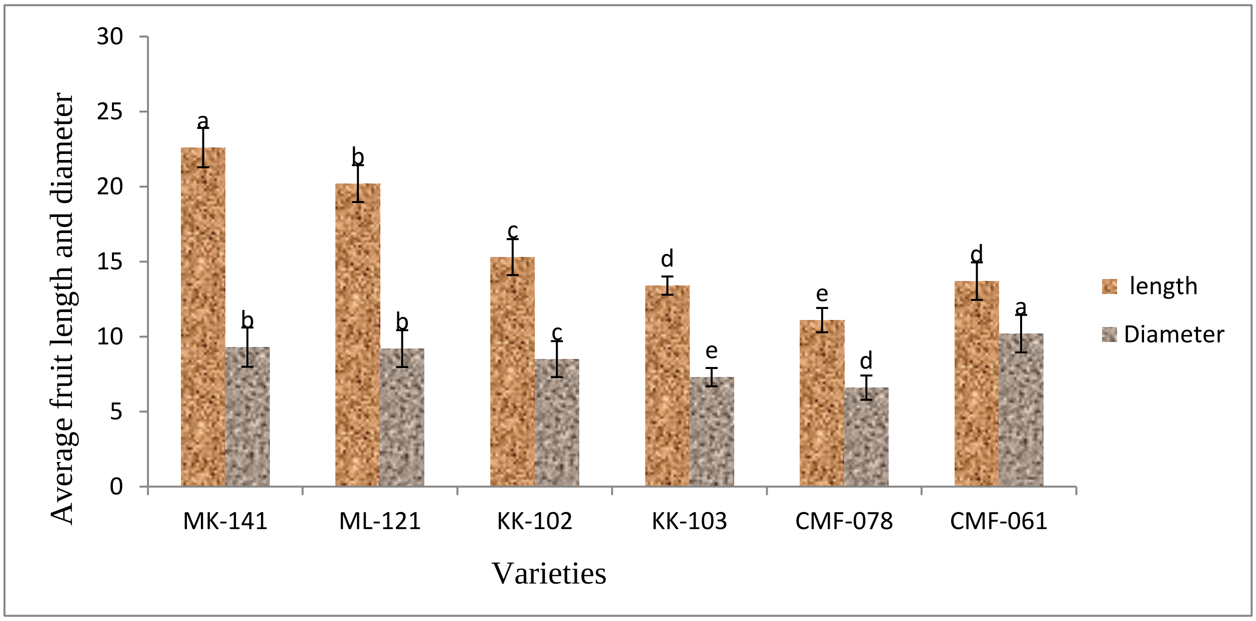

Figure 2. Effect of varieties on the average fruit length and diameter of papaya fruit

Bars capped with different letter are significantly different at (p<0.05).

The fruit diameter was significantly (p<0.05) varied among the six varieties (Appendix Table 5). The range of fruit diameter was found from 6.6 cm to 10.2cm (Figure 3). The variety CMF-061 gave the maximum fruit diameter (10.2cm) followed by variety MK-141 (9.3cm), variety ML-121(9.2cm), KK-102 (8.5cm) and variety KK-103(7.3cm) while it was minimum in variety CMF-078 (6.6cm). This variation could be due to the genetic variation between the different varieties or it could be due to the influence of the environmental factors on the fruit flower.

Nakasone and Paull (1999) reported that fruit from female trees are spherical. The shape of fruit from bisexual trees is affected by environmental factors, particularly temperature that modifies floral morphology during early development of the inflorescence (Nakasone and Paull, 1999). Schwerggert *et al*. (2011) found maximum fruit diameter 11.6 cm which is greater by (1.2 cm) from this finding. Akehter (2011) reported diameter of 20 germplasms and the longest was 10.13cm and the shortest was 3.28cm which is inconsistent with this finding.

4.1.4 Firmness

4.1.4.1 Effect of varieties on fruit firmness

The main effects variety and harvesting maturity on papaya fruit firmness was significant ($p<0.05$).However, their interaction effect was not significant ($p>0.05$) (Appendix Table 6). At the initial harvesting day the highest fruit firmness (42.01N) was recorded from variety Mk-141 followed by variety ML-121(40.1N) and the lowest firmness (38.78N) was recorded from variety CMF-061. At the end of the storage day fruit firmness decrease to (11.65N) in variety MK-141, which is 72.26% and lowest was recorded from variety CMF-061(9.10N), which is 76.94% (Table 2).

Table 2. Effect of varieties on the papaya fruit firmness (N)

Variety	**Days After Storage**			
	0	**2**	**4**	**6**
MK-141	42.01^{a}	30.98^{a}	16.56^{a}	11.65^{a}
ML-121	40.10^{b}	29.57^{b}	14.83^{bc}	10.91^{ab}
KK-102	39.58^{bc}	29.51^{cd}	15.52^{ab}	10.51^{cb}
KK-103	39.91^{bc}	28.93^{cbd}	14.67^{bc}	10.12^{cd}
CMF-078	39.22^{bc}	28.31^{cd}	14.30^{bc}	9.9^{cd}
CMF-061	38.78^{c}	28.14^{d}	14.28^{c}	9.10^{d}
LSD(0.05)	1.30	1.22	1.23	0.94
CV (%)	3.97	5.11	10.04	11.13

Note: Means followed with the same letter(s) are not significantly different.

This result shows there is a firmness difference between the varieties. The observed variation might be due to genetic or environmental factors as confirmed by Beckles (2012). Ilic *et al*. (2012) disclosed that the higher pericarp thickness of a variety, the better is the firmness of fruit. In addition Dargie *et al*. (2013) reported that there is firmness variation between different varieties of sweet pepper. This finding is in agreement with results of Lahay *et al*. (2013) who reported that the value of fruit firmness varied in magnitude between varieties of tomato fruits.

The result indicates that there was firmness loss as the storage day increases. Firmness is the parameter of greatest concern in papaya fruit storage and marketing, because flesh softening is associated with senescence and fruit injuries. The fruit were soft (firmness <11 N) at the sixth days of storage (Table 2). This showed a loss of firmness of the pulp during fruit ripening. This loss in firmness correlated with the activity of α- and β-galactosidases and pectin methylesterase, which influence galactanase activity that modify papaya cell wall materials during ripening (Ali *et al*., 1998). Lahay *et al*. (2013) found a reduction in firmness of fruits during prolonged storage periods. This could be due to high respiration rate and weight loss as supported by (Cantwell *et al*., 2009).

4.1.4.2 Effect of maturity stage at harvest on fruit firmness

Fruits harvested at more advanced maturity stages had lower pulp firmness when compared to those harvested at earlier stages (Table 3). In the first day of harvesting the maximum fruit firmness(42.37N) was recorded from fruit harvested on matured green stage followed by 1/4 yellow skin(40.67N) and the minimum firmness (37.64N) was recorded from papaya fruit harvested on 3/4 yellow skin. At the end of the storage day the maximum firmness (13.23N) was recorded from fruit harvested on green matured stage and the minimum (7.54N) was recorded from fruit harvested on 3/4 yellow skin. This shows the rate of firmness loss was also affected by harvesting maturity (Table 3). Fruit harvested at green matured stage lost 68% of initial firmness, and more than 79.96%when harvested at 3/4 yellow skin stage.

The degradation of pectins, compounds that contribute to fruit structure, produces losses in peel and pulp firmness. The quality of ethylene receptors is reduced in fruits harvested when still green (Trewavas, 1982) and, for this reason, the ethylene dependent process can be delayed. Serry (2011) reported the rate of firmness affected by maturity stage at harvest and fruit harvested at early maturity stage the enzymes related to softening were still not completely synthesized and activated.

Table 3. Effect of maturity stage at harvest on the papaya fruit firmness

Maturity at Harvest	**Days after Storage**			
	0	**2**	**4**	**6**
HM1	42.37^{a}	31.16^{a}	17.03^{a}	13.23^{a}
HM2	40.67^{b}	30.09^{b}	15.86^{b}	11.93^{b}
HM3	39.04^{c}	28.71^{c}	14.34^{c}	8.80^{c}
HM4	37.64^{d}	26.99^{d}	12.89^{d}	7.54^{d}
LSD (0.05)	1.06	1.00	1.01	0.77
CV (%)	3.97	5.11	10.04	11.13

Note: Means with different letter differ significantly (p<0.05)

The present result is in coherence with the findings of Zhou *et al*. (2011) who found a decrease in fruit firmness with increasing harvesting maturity stage. The apparent decline in fruit firmness with age might be due to cell wall softening directly influencing the levels of fruit firmness. This is in line with the work of Rao *et al*. (2011) who found that cell wall softening is due to the activity of softening enzymes such as Pectin methylesterase.

4.2 Chemical Quality of Papaya (*Carica papaya L*)

4.2.1 Total soluble solids (TSS)

4.2.1.1 Effect of varieties on TSS content of papaya fruit same comment

The main effect of the variety and harvesting maturity stages showed a significant (p<0.05) effect on the TSS content of papaya fruit. However, there was no significant (P<0.05) interaction effect of variety and harvesting maturity on the TSS values of papaya fruits. In this experiment during harvesting the total soluble solids were highest in the fruit pulp of KK-102(12.24°Brix) followed by CMF-078(11.93°Brix). The lowest total soluble solids were recorded in the pulp of CMF-061(10.61°Brix) which is not significantly differed from variety Mk-141 and ML-121.At the end of storage day there was an increment on TSS content. On the sixth day of storage maximum TSS content was found from variety KK-102(13.44^{0}Brix) followed by variety CMF-078 (13.14^{0}Brix) (Table 4). The minimum TSS was recorded from variety MK-141 (11.75^{0}Brix), variety CMF-061 (11.88^{0}Brix) and ML-121 (11.92^{0}Brix) which are not statistically differ each other. TSS (Total soluble solid) is an estimate of fruit sugar content and is used as a maturity index and also it judges the qualitative characters of a fruit. The sugar content is important quality attribute of papaya fruits (Ong *et al*., 2013). The observed TSS variation between varieties might be due to genetic or environmental factors as confirmed by Beckles (2012). The values commonly obtained for TSS of papaya ranges from 7.4–19.0°Brix (Wills and Widjanarko, 1995; Paull *et al*., 1997; Wall, 2006; Zaman *et al*., 2006) which is in line with this finding. This finding is also in agreement with (Akhter *et al*., 2012) who reported TSS content of different twenty papaya germplasm and the content range from 10.00-17.1 ^{0}Brix. The increment in TSS might be due to disassociation of some molecules and structural enzymes in soluble compounds, which directly influence the levels of TSS. Fruits with more than 12% TSS are generally considered acceptable to consumers (Stec *et al*., 1989).

Table 4. Effect of varieties on the TSS content of papaya fruit

Variety	Days after Storage			
	0	**2**	**4**	**6**
MK-141	10.88^c	11.06^c	11.44^c	11.75^d
ML-121	10.92^c	10.96^C	11.61^{bc}	11.92^d
KK-102	12.24^a	12.40^a	12.95^a	13.44^a
KK-103	11.37^b	11.42^b	11.88^b	12.49^c
CMF-078	11.93^a	12.10^a	12.69^a	13.14^b
CMF-061	10.61^c	10.92^c	11.50^c	11.88^d
LSD (0.05)	0.42	0.34	0.29	0.26
CV (%)	4.59	3.63	2.99	2.58

Note: Means followed with the same letter(s) are not significantly different.

4.2.1.2 Effect of maturity stage at harvest on TSS content of papaya fruit

The main effect of the harvesting maturity showed a significant ($p<0.05$) (Appendix Table 7) effect on the TSS content of papaya fruit. In the first harvesting day maximum (12.11^{0}Brix) TSS content recorded from fruit harvested on 3/4 yellow skin followed by fruit harvested on1/2 yellow skin (11.55^{0}Brix). The least TSS content was recorded from papaya fruit harvested on green matured stage (10.64^{0}Brix). However, at the end of storage day maximum TSS content was found from papaya fruit harvested 3/4 yellow skin (13.26^{0}Brix). The minimum TSS was recorded from papaya fruit harvested on green matured stage (11.61^{0}Brix).

Table 5. Effect of harvesting maturity on the TSS content of papaya fruit (^{0}Brix)

Maturity at Harvest	**Days after Storage**			
	0	**2**	**4**	**6**
HM1	10.64^d	10.76^d	11.19^d	11.61^d
HM2	11.00^c	11.22^c	11.70^c	12.08^c
HM3	11.55^b	11.78^b	12.36^b	12.80^b
HM4	12.11^a	12.15^a	12.79^a	13.26^a
LSD (0.05)	0.34	0.27	0.24	0.21
CV (%)	4.59	3.63	2.99	2.58

Note: Means followed with the same letter(s) are not significantly different.

The increase in TSS with advancing fruit maturity (HM1 to HM4) might be explained by the hydrolysis of starch to sugars as fruit advances in maturation (Kulkami and Aradhya, 2005). A starch transformation in sugars also takes place, increasing fruit sweetness (TSS) and also influencing texture. Papaya has a low starch content therefore the fruit does not have significant amounts of starch to be hydrolyzed during ripening, which results in little, if any, change in soluble contents during the postharvest period. Due to the low starch amounts in papaya, the carbon source for the observed postharvest rise in sugars is discussed controversially. Since polygalacturonase and β-galactosidase activities increase during ripening, cell wall degradation due to pectin and hemicellulose hydrolysis was assumed to contribute to the boost in TSS (Fabi *et al*., 2007; Lazan *et al*., 1995; Paull, Gross and Qiu, 1999). As reported by Zaman *et al*. (2006) TSS contents of Bangladeshi papayas varied from 9.0° to 13.0°Brix, whereas Unnithan (2008) observed TSS contents between 11.6° and 14.8°Brix for Indian varieties.

4.2.2 Titratable acidity

4.2.2.1 Effect of varieties on TA content of papaya fruit

The main effect of the variety and harvesting maturity had a significant ($P<0.05$) effect on papaya TA content (Appendix Table 8). However, the interaction between varieties and harvesting maturity had no significant ($P<0.05$) effect on the titratable acidity of papaya fruits. In the first storage day, the maximum TA value (0.20%) was recorded from papaya fruit variety

CMF-061 and the minimum (0.17%) TA value was recorded from papaya fruit variety KK-102. TA decreases as ripening increases from the first storage date to the end of the storage day. At the end of the storage day the TA value decreased to 0.09 to 0.07 in Varity CMF-061 and in variety CMF-078 respectively. This finding is in line with Camara *et al.* (1993) who reported similar TA values of papaya fruits with a range varying from 0.20% to 1.0%. Bron and Jacomino (2006) reported that the ranges of TA on fresh Golden papaya fruits were 0.09 –0.12%.

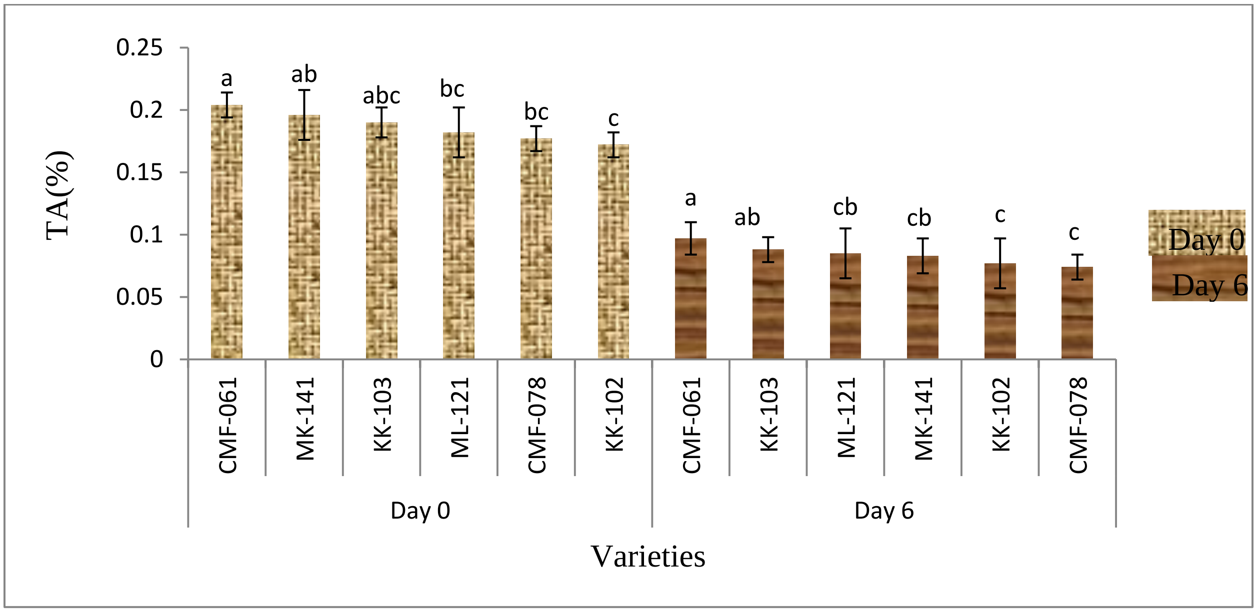

Figure 3. Effect of Varieties on the TA content of papaya fruit

Bars capped with the same letter(s) are not significantly different at p < 0.05.

4.2.2.2 Effect of maturity stage at harvest on TA content of papaya fruit

The main effect of the harvesting maturity showed a significant ($p<0.05$) (Appendix Table 8) effect on the TA content of papaya fruit. At the first harvesting day maximum (0.22%) TA content was recorded from fruit harvested on green matured stage followed by fruit harvested on1/4 yellow (0.19%) (Figure 5). The least TA content was recorded from papaya fruit harvested on ¾ yellow skin stages (0.16%). However, at the end of the storage day the TA content were decreased on the four harvesting maturity stage.

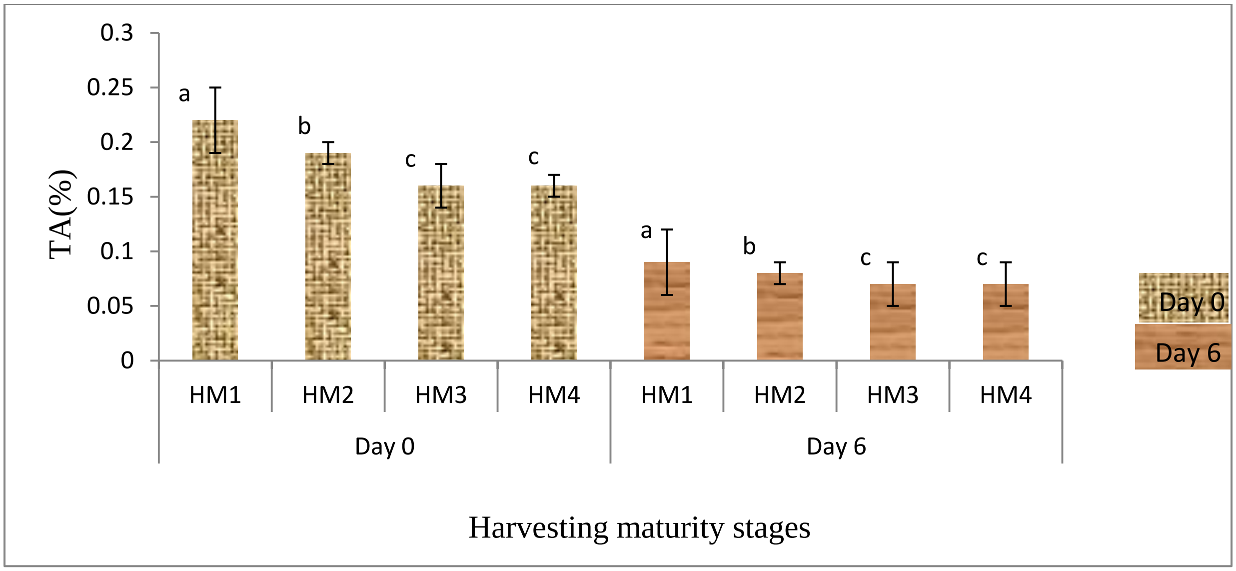

Figure 4. Effect of harvesting maturity on the TA content of papaya fruit

Bars capped with the same letter(s) are not significantly different at p < 0.05.

Serry (2011) reported that TA in papayas was reduced during ripening. According to, Lazan *et al*. (1989) the TA increases with fruit ripening until approximately 3/4 of yellow skin decreasing thereafter. During fruit ripening, titratable acidity was reported to increase up to the climacteric peak and declined afterwards in papaya (Selvaraj *et al.,* 1982). These results support the view that acids can be used as substrates for respiration when sugars have been consumed or participated in the synthesis of phenolic compounds, lipids and volatile aromas and provide in addition, a series of metabolites which are used in many processes that reflect dominance of sweet flavor in papaya fruit (Ulrich, 1970).

4.2.3. Effect of Variety and maturity stage at harvest on ascorbic acid of papaya fruit

In this finding the analysis of variance indicated that, the interaction effect of variety and harvesting maturity was significant at ($p < 0.05$) (Appendix Table 9) for *vitamin C* content in papaya fruit. As indicated in (Table 6) the mean value of *vitamin C* content in papaya pulp was in the range of (35.01mg/100g- 75.55 mg/100g). The highest value (75.55 mg/100g) of *vitamin C* content was recorded in KK-103 harvested on 3/4 yellow skin followed by CMF-078 harvested on 3/4 yellow skin however; the lowest value (35.01mg/100g) of *vitamin C* content was recorded in ML-121harvested on green matured stage. In this finding the vitamin C content was increase with the increasing harvesting maturity.

The variation in *vitamin C* content among the papaya fruit varieties might be mostly because of the variation within the varieties and due to the variation in the harvesting maturity stages. According to (Podsedek, 2007; Lee and Kader, 2000) the vitamin C content in fruits can be influenced by various factors such as genotype differences, climatic conditions, soil state, maturity at harvest and harvesting methods.

Table 6 Interaction effects of varieties and harvesting maturity stage on vitamin C content of papaya fruit.

Varieties	HM	Ascorbic acid(mg/100g)
MK-141	HM4	57.21[fg]
	HM3	54.61[hi]
	HM2	48.42[kl]
	HM1	42.93[m]
ML-121	HM4	70.39[b]
	HM3	65.76[de]
	HM2	58.62[f]
	HM1	50.85[j]
KK-102	HM4	64.27[e]
	HM3	59.25[f]
	HM2	55.98[hg]
	HM1	52.44[ij]
KK-103	HM4	75.557[a]
	HM3	67.34[cd]
	HM2	54.22[hi]
	HM1	46.6[i]
CMF-078	HM4	75.42[a]
	HM3	68.47[bc]
	HM2	64.56[e]
	HM1	51.59[j]
CMF-061	HM4	65.18[de]
	HM3	50.35[jk]
	HM2	43.18[m]
	HM1	35.01[n]

Note: Means followed with the same letter(s) are not significantly different.

Bari *et al*., (2006) and Hernandez *et al*., (2006) reported that papaya is a source of vitamin C with amounts varying between the maturation stages. Variation in vitamin C content was also reported among papaya varieties (Franke *et al*., 2004; Wall, 2006). The higher the intensity of light during the growing season, the greater is vitamin C content in plant tissue (Lee and Kader, 2000). According to Wall, (2006) the average vitamin C content of papayas was 51.2 mg/100 g and for all papayas harvested from 60 plants throughout the state, the vitamin C content ranged from 36.3 to 67.8 mg/ 100 g.

4.2.4. Effect of Variety and harvesting maturity on β-carotene content of papaya fruit

In this finding the content of beta carotene increased with fruit maturity stage. The analysis of variance indicated that, the interaction effect of variety and harvesting maturity was significant at ($P<0.05$) (Appendix Table 10) for β-carotene content in papaya fruit. As indicated in (Table 7) the mean value of β-carotene content in papaya pulp was in the range of (242.67μg/100g-1138.33μg /100g). Early matured stages in the whole varieties were characterized by low amounts of β-carotene. The highest value (1138.33 μg /100g) of β-carotene content was recorded in KK-102 harvested on 3/4yellow skin followed by KK-103 harvested on 3/4 yellow skin. The lowest value (242.67μg/100g) of β-carotene content was recorded in CMF-078 harvested at green matured stage. The variation in β-carotene content might be mostly because of the variation within the varieties and due to the variation in the harvesting maturity stages. The differences in the methods of analysis have been shown to contribute to the variations in β-carotene content (Rodriguez-Amaya *et al.,* 2008). Puwastien *et al*. (2000) and Saxholt *et al*. (2008) reported that the content of beta carotene varies from 866 μg/100g to 7,807 μg /100g dry matter in ripe fruits.

According to Laura, 2011 the concentrations of the carotenoids found in saponified papaya pulp expressed in mg/100 g DW were increased from 0.24 mg/100 g DW (in MS1) to 0.5 mg/100 g DW (in MS4). During maturation, chlorophyll began to degrade, coinciding with carotenoid synthesis and resulting in a significant increase of yellow–orange color. Some tropical fruits such as mangos have a similar behavior as papaya, where color conferred by carotenoids plays an important role in the fruit acceptability by consumers (Yahia and Ornelas-Paz, 2010).

Table 7. Interaction effect of varieties and harvesting maturity stage on beta carotene content of papaya fruit.

Varieties	HM	Beta carotene(μg/100g)
MK-141	HM4	804.33 [de]
	HM3	637.67 [f]
	HM2	367.33[g]
	HM1	269.67 [i]
ML-121	HM4	874.33[c]
	HM3	656.33[f]
	HM2	360[g]
	HM1	278[hi]
KK-102	HM4	1138.33[a]
	HM3	1050.33[b]
	HM2	871.67[c]
	HM1	671[f]
KK-103	HM4	1137.33[a]
	HM3	1027[b]
	HM2	865.67[cd]
	HM1	657.67[f]
CMF-078	HM4	873.33[c]
	HM3	614[f]
	HM2	338.67[gh]
	HM1	242.67[i]
CMF-061	HM4	771[e]
	HM3	617.33[f]
	HM2	348[g]
	HM1	260[i]

Note: Means followed with the same letter(s) are not significantly different.

In addition to this the differences could be attributed to agricultural practices, sunlight exposure, production area, stage of maturation, postharvest handling, and methodology used for analysis (Andersson *et al.*, 2009; De Rosso and Mercadante, 2005; Ornelas-Paz *et al*., 2008). A study performed by Kimura *et al*. (1991) in “Common”, “Solo”, “Formosa” and “Tailandia” papaya, reported the effect of agricultural practice on the content of carotenoids of papaya fruit.

Beta carotene content contributes to the color of papaya pulp (Chandrika *et al*., 2003). Coinciding with pulp color development, a striking diversity of mesocarp carotenoids evolved during fruit maturation (Schweiggert *et al*., 2013). Carotenoids, especially α– and β-carotene which are potential provitamin A precursors that can be converted into retinol, are present in plant products, especially in yellow and orange fruits (Schweiggert *et al*., 2013).

4.2.5. Effect of Variety and Maturity Stage at Harvest on Proximate Composition of Papaya Fruit

The proximate composition includes moisture, ash, crude protein, crude fat, crude fiber and carbohydrate estimation (James, 1995). The proximate composition of the six different varieties of *Carica papaya* on four different stage of harvesting maturities was investigated and presented in Table 6. The results of the carbohydrate, moisture, protein, ash, crude fiber and crude fat content of the fruits are discussed below.

I. Protein content

Protein is needed for physiological functioning and reducing protein-energy malnutrition (WHO, 2004).The result obtained from the analysis of variance indicated that, the interaction effect of variety and harvesting maturity was highly significant at ($p<0.001$) for protein content (Appendix Table 11). The mean value of protein content of the samples was in the range of (3.98-7.83%). The highest value (7.83%) was observed from variety CMF-061 harvested on stage 3/4 yellow skin harvesting maturity which is statistically similar with variety CMF-061 harvested on ¼ harvesting maturity. The lowest value (3.56%) was recorded from Variety CMF-078 harvested on green matured harvesting maturity stage (Table 8). The results from the study have shown that protein content increased as the papaya harvesting maturity stage increase. This increase in protein may be as a result of transcription of many mRNA in the nucleus. These transcribed mRNA are transported to the cytoplasm for the synthesis of enzymes required for the ripening process, solubilization of peptic substances, degradation of starch and inter-conversion of sugar, synthesis of pigment etc (Grierson, 1986). The result obtained was in consistent with the report of OECD (2010) that protein ranged between 5.48-10.8% in the unripe papaya fruit.

Π. Fat content

Plant fat is a good source of energy and helps in absorption of most fat soluble vitamins and minerals (WHO, 2004). The effect of variety and harvesting maturity on crude fat content was highly significant at ($p < 0.001$) (Appendix Table 12). The mean value of fat content of the samples was in the range of (0.92-3.63%) (Table 8). The highest value (3.63%) was observed from variety CMF-061 harvested on 3/4 yellow skin which is not statistically different from variety CMF-078 harvested on 3/4 yellow skin. The lowest value (0.92%) was recorded from Variety CMF-078 harvested on green matured harvesting maturity stage (Table 6). In this finding as the harvesting maturity stage increases in the fruit variety the fat content also increases. The result is in line with the finding of Wurochekke *et al.* (2013) who reported that the fat content in the three varieties increased with maturity. In addition the result obtained was in consistent with the report of QECD (2010) in which the fat content varies between 0.92 and 2.2 g/ 100 g dry matter.

Table 8 . Proximate composition of six papaya fruit varieties harvested on four maturity stages at harvesting

Variety	Maturity at Harvest	C. Pro (%)	Fat (%)	Ash (%)	C. Fib (%)
MK-141	HM1	4.24^{l}	0.97^{mn}	8.20^{c}	13.30^{a}
	HM2	4.78^{jk}	1.30^{lk}	7.56^{d}	12.54^{b}
	HM3	5.35^{fgh}	1.71^{ghi}	6.54^{f}	11.22^{cd}
	HM4	5.99^{cd}	2.07^{ef}	4.70^{k}	10.42^{f}
ML-121	HM1	4.75^{jk}	1.13^{lm}	9.42^{a}	13.57^{a}
	HM2	4.97^{hijk}	1.48^{jk}	8.50^{b}	12.79^{b}
	HM3	5.48^{ef}	1.73^{gh}	7.21^{e}	11.46^{c}
	HM4	5.82^{de}	3.35^{b}	6.48^{fg}	9.29^{i}
KK-102	HM1	4.86^{ijk}	1.11^{lmn}	6.54^{f}	10.95^{de}
	HM2	5.47^{efg}	1.50^{hij}	5.10^{j}	9.61^{gh}
	HM3	5.84^{de}	2.27^{de}	4.35^{m}	8.63^{j}
	HM4	6.01^{cd}	3.35^{b}	3.58^{o}	6.87^{l}
KK-103	HM1	4.62^{jkl}	1.49^{jk}	6.58^{f}	11.32^{c}
	HM2	5.03^{ghij}	1.68^{hij}	5.39^{i}	10.55^{f}
	HM3	5.45^{efg}	1.91^{fg}	4.27^{m}	9.44^{hi}
	HM4	5.53^{ef}	2.29^{d}	3.72^{on}	8.63^{j}
CMF-078	HM1	3.56^{m}	0.92^{n}	6.30^{g}	9.79^{g}
	HM2	4.58^{kl}	1.69^{jhi}	4.56^{kl}	8.44^{j}
	HM3	5.00^{hijk}	2.26^{de}	4.45^{lm}	7.20^{k}
	HM4	5.29^{ghij}	3.57^{a}	3.82^{n}	6.40^{m}
CMF-061	HM1	6.29^{c}	1.36^{k}	9.3^{a}	11.43^{c}
	HM2	6.76^{b}	2.09^{def}	7.27^{e}	10.73^{ef}
	HM3	7.39^{a}	3.07^{c}	5.35^{i}	9.30^{hi}
	HM4	7.83^{a}	3.63^{a}	4.63^{kl}	8.35^{j}

LSD (0.05%)	0.44	0.21	0.18	0.31
CV (%)	4.75	0.64	0.87	1.86

Mc-Moisture ; C. Pro- Crude protein; C. Fib-Crude Fiber; CHO-Carbohydrate

Mean values followed by the same letter(s) in the column are not significantly different at p < 0.05

III. Fiber Content

The crude fiber composition of papaya fruit was highly significantly ($p < 0.001$) affected by variety and harvesting maturity see (Appendix Table 13). As indicated in (Table 8) the mean value of fiber was in the range of (6.17-13. 57%). The highest value (13. 57%) was observed from variety ML-121 harvested on green matured fruit followed by MK-141 harvested on matured green stage, which is statistically not different from ML-121 harvested on green matured stage. The lowest value (6.4%) was recorded from Variety CMF-078 harvested 3/4 yellow skin. Papayas contain soft, easily digestible flesh with a good amount of soluble dietary fiber that helps to have normal bowel movements; thereby reducing constipation and aids nutrient absorption (Onwuka, 2005).

Fiber plays a role in reduction of cholesterol in the blood. In this finding crude fiber was discovered to decrease with maturity. This may be as a result of breakdown of polymeric carbohydrate, which resulted in the weakening of cell wall (Bartley and Knee, 1982). Paull and Chen (1983) also reported the decrease in fiber content as the fruit matures may be as a result of increase in pectinmethylesterase activities. This finding is in consistent with Chukwuka *et al*. (2013) that crude fiber content was highest in the unripe fruit. In his finding, the unripe pulp contained 11.62% fiber which is in line with this finding.

IV. Ash content

The interaction effect of variety and harvesting maturity on ash content of papaya fruit was highly significant at ($p<0.0001$) as indicated in (Appendix Table 14). The ash content of the samples was within the range of (3.58-9.42%) (Table 8).The highest value (9.42%) for ash content was observed in variety MK-141 harvested on green matured harvesting maturity which is statistically not different from Variety CMF-061 harvested on matured green harvesting maturity. The lowest value (3.58%) was from KK-102 harvested on 3/4 yellow skin harvesting maturity. Ash content indicates an estimate of the total mineral content in a given quantity of food substance (Neha and Ramesh, 2012).This finding is in line with finding of Chukwuka *et al*. (2013) who indicate the percentage ash varies in fruit maturity stage and the highest percentage ash was found in pulp at green matured stage and lowest in the pulp at hard ripe stage. In addition study done by Wurochekke *et al*. (2013) on three different papaya varieties indicates that ash content decreased with maturity.

4.3 Sensory Quality

4.3.1 Effect of Varieties and Harvesting Maturity on the Sensory Quality of Papaya Pulp

Papaya fruit pulp from different varieties and harvesting maturity showed significant interaction effect at ($p<0.05$) (Appendix Table 16) for color, flavor, taste and overall acceptability. Sensory evaluation mean scores of a 5- point hedonic scale results are presented in Table 9. The highest mean value (4.36) for color of papaya fruit pulp was recorded from papaya fruit variety KK-102 harvested on 1/2 yellow skin fruit whereas, the lowest color value(3.20)was obtained from variety CMF-061 harvested on green matured fruit, which is not significantly differed from variety ML-141 , ML-121 and CMF-061 harvested on 1/2 yellow skin. Since papaya has low acidity, flavor is attributed mainly to sugar content. The value of flavor for papaya fruit pulp varies between (3.12 -4.32). The maximum value corresponds to papaya fruit variety KK-102 harvested on 1/2 yellow skin. However, the lowest value for flavor refers to papaya fruit variety MK-141 harvested on green matured stage.

The highest mean value (4.80) for taste of papaya fruit pulp was recorded from variety KK-102 harvested on 1/2 yellow skin, whereas, the lowest taste value (2.82) was obtained from CMF-061 harvested on green matured stage. The value of overall acceptability of papaya fruit pulp varies between (3.18 and 4.50). The maximum value corresponds to papaya fruit variety KK-102 harvested on 1/2% yellow skin followed by the KK-102 harvested on1/4 yellow skin. But, the lowest value for overall acceptability refers to papaya fruit variety CMF-061 harvested on 3/4 yellow skin. Comparing the result obtained in sensorial analysis (Table 7) with soluble solid values (Table 6 and 9), it is noticeable that the panelists detected the differences found in soluble solids. The obtained result indicates harvesting at green matured stage and at ¾ yellow skin stage decrease fruit quality but did not make the fruit unacceptable for consumption.

The findings of the sensory evaluation showed that the overall acceptance increased corresponding to the progress of ripening stages of papaya based on color, flavor and taste. The color, flavor and taste produced from 1/2 yellow skin harvesting maturity and ripened for fourth day were found to be the most preferred following by papaya fruit varieties harvested on 1/4 yellow skin in comparison to those from the other papaya fruit harvested on 3/4%yellow skin and green matured stage.

Table 9 . Consumer acceptance of papaya fruit samples of six varieties harvested on four different stages of maturity at harvesting

Variety	**Maturity at Harvesting**	**Color**	**Flavor**	**Taste**	**Overall acceptability**
MK-141	HM1	3.44^{hij}	3.12^{k}	3.38^{ij}	3.40^{hi}
	HM2	3.38^{ij}	3.42^{jk}	3.40^{ij}	3.44^{hi}
	HM3	3.20^{j}	3.38^{jk}	3.88^{fg}	3.78^{efg}
	HM4	3.38^{ij}	3.42^{jk}	3.54^{hi}	3.96^{cde}
ML-121	HM1	3.26^{j}	3.18^{jk}	3.54^{hi}	3.28^{i}
	HM2	3.70^{hi}	3.50^{ij}	3.70^{gh}	3.80^{efg}
	HM3	3.22^{j}	3.60^{hi}	4.20^{cde}	4.00^{cde}
	HM4	3.64^{ghi}	3.72^{fg}	3.54^{hi}	3.38^{hi}
KK-102	HM1	4.00^{ef}	4.10^{ab}	4.36^{bcd}	4.16^{bc}
	HM2	4.30^{ab}	4.12^{ab}	4.54^{ab}	4.32^{ab}
	HM3	4.36^{a}	4.32^{a}	4.80^{a}	4.50^{a}
	HM4	4.04^{ef}	4.02^{abc}	4.44^{bc}	4.14^{bcd}
KK-103	HM1	3.98^{fg}	3.40^{jk}	3.74^{gh}	3.58^{fgh}
	HM2	4.06^{de}	3.68^{gh}	4.14^{def}	4.04^{cde}
	HM3	4.02^{ef}	3.87^{de}	4.45^{bc}	4.20^{cb}
	HM4	3.80^{fg}	3.44^{jk}	3.80^{gh}	3.5^{gh}
CMF-078	HM1	3.90^{fg}	3.80^{ef}	3.90^{fg}	3.80^{efg}
	HM2	4.20^{abc}	3.98^{bcd}	4.32^{bcd}	4.16^{bc}
	HM3	4.10^{cd}	4.02^{abc}	4.58^{ab}	4.22^{bc}
	HM4	3.80^{fg}	3.44^{jk}	3.80^{gh}	3.84^{ef}
CMF-061	HM1	3.74^{efg}	3.32^{ijk}	2.82^{k}	3.26^{i}
	HM2	3.92^{fg}	3.30^{ijk}	3.92^{def}	3.88^{de}
	HM3	$3.44h^{ij}$	3.40^{jk}	3.56^{hi}	3.40^{hi}
	HM4	3.20^{j}	3.24^{jk}	3.16^{j}	3.18^{i}
LSD (0.05%)		0.346	0.331	0.288	0.276
CV%		23.54	23.35	18.83	18.49

It must be noted that as starch in fruits is changed into sugars during ripening process, the taste changes to sweet as a result of increased sugar composition contributing to the taste of the fruit (Kader, 2008).In addition, the sweeter taste fruit could be associated with a softer texture, which would facilitate mastication and liberation of the sugars for the sensory perception (Gomez, 2002.). According to (Sarananda and Wijesundara, 2009) thick red color flesh in ripe fruits attracts the consumer.

The declining acceptance of papaya fruit with ripening may be because of the softening of the pulp, high moisture and high total soluble solids composition when the fruit is completely ripe. This result corresponds with the study of Bender *et al*. (2000). This finding is also in line with the finding of Bron and Jacomino (2006) who reported higher acceptability from fruit harvested on 16-25% and 26-50% yellow skin than fruit harvested on totally green and <15% yellow skin and ripened at room temperature until it reach the edible maturity. In addition Serry (2011) found higher scores attributes from fruit harvested at 50% yellow.

5. SUMMARY AND CONCLUSION

Ethiopia is suitable for the production of a variety of fruit crops, of which papaya *Carica papaya* is one of the few under–exploited crops with promising economic value for the country and yet Ethiopia has not benefited much from the crop. This is partly due to the limited information available on the physicochemical and sensory quality of the existing papaya varieties.

In view of this an experiment was conducted with the objective to evaluate effect of maturity stage at harvesting on the physicochemical and sensory quality of fruits of selected papaya varieties. Six papaya varieties (MK-141, ML-121, KK-102, KK-103, CMF-078, CMF-068) from Melkassa national fruit coordination center were taken, and harvested at four stages of maturity (Green matured, 1/4% yellow skin, 1/2% yellow skin and 3/4 yellow skin) in year 2013. The experiment was conducted using a randomized 6*4 factorial design with three replications.

In this study, the influence of the varieties and maturity stages at harvesting on the physical-chemical and sensory quality of papaya fruit was investigated. The six different varieties and the four harvesting maturity and the combined effect among the different varieties and maturity at harvesting showed significant effect on the physicochemical and sensory quality of the fruit. The observed results indicated there was a highly significant effect on the physical quality due to varietal differences. Accordingly, variety MK-141 and ML-121 can be categorized as large fruit and variety CMF-068 and KK-102 as medium and variety kk-103 and CMF-078 as small fruit.

There was a significant effect due to the effect of varieties and maturity stages at harvesting on the fruit firmness. The maximum firmness was recorded from variety ML-141 and minimum was recorded from CMF-068. Fruits harvested on more advanced maturity stage recorded lowest firmness and the highest were recorded from fruit harvested on less advanced stage. There was more than 60% firmness loss at the end of storage day and in all the six varieties firmness was below 20N at the end of storage day.

The main effect of varieties and maturity stage at harvest had a highly significant effect on the TSS content of papaya fruits. The maximum TSS (13.44^{0}Brix) content was recorded from variety KK-102 followed by Variety CMF-078 (13.14^{0}Brix) and the least TSS content was recorded from variety MK-141 (11.75^{0}Brix). In addition, the higher TSS content recorded from papaya fruits harvested on more advanced maturity stage at harvesting. As the storage day increased there was increment in TSS content. This may be due to hydrolysis of starch during fruit ripening.

Similarly, the main effect of variety and harvesting maturity had a significant effect on TA content of papaya fruit. The maximum TA content recorded from variety CMF-061(0.09%) and the minimum was recorded from papaya fruit variety KK-102 (0.07%). As the storage day increase the TA content decrease. Harvesting maturity had significant effect on the TA content of papaya fruit. TA content was maximum on fruit harvested at more advanced stage on the initial storage day. However, TA content decrease as the storage day increases.

In the case of ascorbic acid, the two main effects have significant interaction effect on papaya fruit ascorbic acid content. The maximum content (75.55mg/100g) of ascorbic acid content was recorded from variety KK-103 harvested on 3/4 yellow skin and the minimum value (35.01mg/100g) of ascorbic acid content was recorded from variety ML-121 harvested on green matured stage. In this finding β-carotene content was increased with fruit maturity and there was significant interaction effect between variety and harvesting maturity. The maximum (1138.33 μg /100g) β-carotene content was recorded from varietyKK-102 harvested on 3/4% yellow skin and the minimum (242.67μg/100g) was recorded from papaya fruit variety CMF-078 harvested at green matured stage.

In the case of proximate composition, there was a significant interaction effect of varieties and harvesting maturity on the protein, fat, fiber and ash content of papaya fruit varieties. In this experiment as the stage of harvesting maturity increase from green matured to 3/4 yellow skin in the whole the six papaya fruit varieties the protein content and the fat content found to be increasing while the fiber and ash content showed a decreasing trend.

In sensory analysis, the highest scores were attributed to fruit harvested at advanced maturity stages, when the edible condition was reached. There was a significant interaction effect between varieties and harvesting maturity stage on the sensory attributes of papaya fruit. In this experiment a significant interaction effect was recorded between varieties and harvesting maturity on color, flavor, taste and overall acceptability.

Therefore it can be concluded that the result of the current study showed that the various varieties and harvesting maturity stage and their interaction have sound impact on the physicochemical quality of *carica papaya*. Generally, during the first harvest day papaya fruit varieties harvested on more advanced stage recorded higher score in all quality parameters. However, as the storage day increased there was a reduction in the score of different quality parameters. Considering overall quality of the fruit, the recommendation may be based on the purpose of the fruit intended for final use. If the fruit is intended for immediate consumption it is recommended to harvest 1/2 and 3/4 yellow skin stages. However for long distance transportation and for storage purpose it is recommended to harvest the fruit on 1/4 and green matured stage.

Even though a fruit is physic-chemically acceptable, still good sensory quality is more important for fresh eaten fruits. The highest score was attributes to fruit harvested at 1/2 yellow skin maturity stage and 1/4 yellow skin maturity stage respectively at the fourth storage day. All sensory attributes namely color; flavor, taste and overall acceptability were 3 and above the scale of 3 in the whole six papaya fruit varieties except in variety CMF-061 harvested on green matured stage. This indicates that the whole six varieties harvested on the four different harvesting maturity stage are in acceptable range.

Finally, this research has helped to establish a relationship between variety and harvesting maturity stage in *Carica papaya* fruit quality. Farmers and other stakeholders are encouraged to produce and harvest papaya fruit based on the role played by this varieties on different harvesting maturity stage.

So, synchronizing during harvesting might be needed to have acceptable good quality fruit in the market and to make consumer beneficiary. Thus, producers and consumer of *Carica papaya* better to be aware of the quality issues and may use the recommendation of this research work for maintenance of good quality and to be beneficiary, depending on the intended use.

FUTURE LINE OF WORKS

- Further detailed nutritional analysis on fruits harvested at different maturity stages and stored under different condition.

- Development of more simple, objective and least cost method of determining maturity indices for papaya harvesting as a function of market and purpose.

- Determine appropriate stages of maturity for harvest for different value added products such as juices, fruit leathers and dried papaya.

- Assessment of physicochemical and sensory qualities of papaya fruits of different sex and pulp color.

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APPENDIX

7. APPENDIX

Appendix Table 1: Characteristics of the main papaya cultivar

	Characteristic	**Solo Group**	**Sunrise solo**	**Golden**	**Formosa**	**Maradol**
1	Origin	Barbados	Hawai	Brazil	Taiwan	Cuba
2	Fruit wt (g)	450-900	465	300-463	1,300-2,700	1,500-2,500
3	Shape	Hermaphordite Pyriform (Female round)	Hermaphordite Pyriform with slight neck (Female round)	Hermaphordite Pyriform (Female round)	Hermaphordite Elongated Female-Round	Hermaphordite Pyriform Female round
4	Skin color	Yellow	Yellow-orange	Yellow-orange	Orange	Bright orange
5	Flesh color	Orange - reddish	Reddish-pink	Orange	Reddish orange	Red-salmon
6	Seed cavity	Deeper than sunrise solo	Not very deep	Not very Deep	Not deep	Not deep
7	Taste	13^0-16^0 Brix, Very sweet	12^0-15^0 Brix Very sweet	12^0-13^0 Brix Sweet	11^0-14^0Brix Sweet	12^0-13^0 Brix Sweet
8	Aroma	Nice	Nice	Nice	Mild	Strong
9	Height, fruit dev't (cm)	90	90	70	60-80	50
10	Market Fresh Local Export	Table Good Good	Table Very good Very good	Table Very good Very good	Table Very good Very good	Table/Processing Very good Very good
	Other highlights	Thick skin good for shipping	Low sterility Thick skin good for shipping	Thick skin good for shipping	High productivity long shelf life	Thick skin good for shipping long shelf life

Source: Bron and Jacomino (2006); Caricom (2006)

Appendix Table 2: Details of treatment combinations (Papaya variety with harvest maturity stages)

Varieties	Maturity at Harvesting	Treatment combination
MK-141(V1)	Green matured (M1)	V1M1
	1/4 yellow skin, (M2)	V1M2
	1/2 yellow skin (M3)	V1M3
	3/4 yellow skin (M4)	V1M4
ML-121(V2)	Green matured (M1)	V2M1
	1/4 yellow skin, (M2)	V2M2
	1/2 yellow skin (M3)	V2M3
	3/4 yellow skin (M4)	V2M4
KK-102(V3)	Green matured (M1)	V3M1
	1/4 yellow skin, (M2)	V3M2
	1/2 yellow skin (M3)	V3M3
	3/4 yellow skin (M4)	V3M4
KK-103(V4)	Green matured (M1)	V4M1
	1/4 yellow skin, (M2)	V4M2
	1/2 yellow skin (M3)	V4M3
	3/4 yellow skin (M4)	V4M4
CMF-078(V5)	Green matured (M1)	V5M1
	1/4 yellow skin, (M2)	V5M2
	1/2 yellow skin (M3)	V5M3
	3/4 yellow skin (M4)	V5M4
CMF-061(V6)	Green matured (M1)	V6M1
	1/4 yellow skin, (M2)	V6M2
	1/2 yellow skin (M3)	V6M3
	3/4 yellow skin (M4)	V6M4

V1=Variety ML= 141; V2=Variety MK-121; V3=Variety KK-102; V4=Variety KK-103; V5=Variety CMF-078; V6=Variety CMF-061;
M1=Green matured; M2=1/4 yellow skin; M3= 1/2 yellow skin; M4=3/4 yellow skin

Appendix Table 3: Over all ANOVA table for Single fruit weight

Source of variation	Df	Mean Square	F Value	Pr >F
Var	5	875510.389	14908.4	0.0001***
HM	3	1.188	0.02	0.9960^{ns}
Var*Rs	15	11.252	0.19	0.9994

CV=1.25% R-Square=0.99 LSD=6.6

Appendix Table 4: Over all ANOVA table for Length of papaya fruit

Source of variation	Df	Mean Square	F Value	Pr >F
Var	5	231.4989	70.19	<0.0001***
HM	3	3.93	1.19	0.3219^{ns}
Var*Rs	15	2.36	0.72	0.7562^{ns}

CV=11.30 R-Square=0.88 LSD=1.49

Appendix Table 5: Over all ANOVA table for Diameter of papaya fruit

Source of variation	Df	Mean Square	F Value	Pr >F
Var	5	203.700599	329.90	<0.0001***
HM	3	0.209002	0.34	0.8868^{ns}
Var*Rs	15	0.322382	0.52	0.3241^{ns}

CV=5.02 R-Square=0.80 LSD=0.64

Appendix Table 6: Over all ANOVA table for Firmness of papaya fruit

Source of variation	Df	Mean Square	F Value	Pr >F
Var	5	6.654	3.81	0.0055
HM	3	80.322	45.99	<.0001
Var*Rs	15	1.582	0.91	0.5628
LSD(A)				1.08
(B)				0.88
CV%				10.87

Appendix Table 7: Over all ANOVA table for TSS

Source of variation	Df	Mean Square	F Value	Pr >F
Var	5	6.09147222	54.96	<.0001
HM	3	9.61717593	86.77	<.0001
Var*Rs	15	0.08695370	0.78	0.6876
LSD(A)				0.27
(B)				0.22
CV%				2.67

Appendix Table 8: Over all ANOVA table for TA

Source of variation	Df	Mean Square	F Value	Pr >F
Var	5	0.00079839	4.26	0.0028
HM	3	0.00346272	18.47	<.0001
Var*Rs	15	0.00006457	0.34	0.9864
LSD(A)				0.011
(B)				0.009
CV%				16.20

Appendix Table 9: Over all ANOVA table for Ascorbic acid composition

Source	Df	Mean square	F value	Pr ≥ F
Var	5	506.057	277.26	<.0001
HM	3	1516.673	830.96	<.0001
Var*Rs	15	39.625	21.71	<.0001

CV=2.35 R-square=0.98 LSD=2.21

Appendix Table 10: Over all ANOVA table for β- carotene composition

Source	Df	Mean square	F value	Pr ≥ F
Var	5	534639.381	374.20	<.0001
HM	3	1041469.606	728.93	<.0001
Var*Rs	15	7131.706	4.99	<.0001

CV=5.76 R-square=0.98 LSD=62.05

Appendix Table 2: Over all ANOVA table for protein composition

Source	Df	Mean square	F value	Pr ≥ F
Var	5	8.694	128.46	<.0001
HM	3	2.094	30.95	<.0001
Var*Rs	15	0.959	14.18	<.0001

CV=4.75 R-square=0.95 LSD=0.44

Appendix Table 3 Over all ANOVA table for fat composition

Source	Df	Mean square	F value	Pr ≥ F
Var	5	1.701	101.92	<.0001
HM	3	9.214	551.95	<.0001
Var*Rs	15	0.405	24.30	<.0001

CV=0.64 R-square=0.98 LSD=0.21

Appendix Table 4: Over all ANOVA table for fiber composition

Source	Df	Mean square	F value	Pr ≥ F
Var	5	28.263	789.12	<.0001
HM	3	39.321	1097.85	<.0001
Var*Rs	15	0.327	9.15	<.0001

CV=0.87 R-square=0.99 LSD=0.31

Appendix Table 5: Over all ANOVA table for ash composition

Source	Df	Mean square	F value	Pr ≥ F
Var	5	19.250	1559.64	<.0001
HM	3	36.516	2958.51	<.0001
Var*Rs	15	0.662	53.71	<.0001

CV=1.86 R-square=0.99 LSD=0.18

Appendix Table 6 Over all ANOVA table for Sensory analysis

Source of variation	Df	Color	Flavor	Taste	Overall Acceptability
Var	5	<.0001	<.0001	<.0001	<.0001
HM	3	0.0008	0.0002	<.0001	<.0001
Var*Rs	15	0.0072	0.0451	<.0001	<.0001
LSD		0.34	0.33	0.28	0.27
CV%		23.54	23.35	18.83	18.49

Appendix Table 7 Questionnaire for sensory evaluation by untrained panelist

Msc Post Harvest Management, Department of Postharvest Management

SENSORY EVALUATION BALLOT: HEDONIC TEST USING UNTRAINED PANALIST

DATE…………………

PRODUCT…………………

INSTRUCTION

Please look at and taste each sample of papaya slice in the order of left to right as shown on the ballot. You are kindly requested to rinse your mouth with water provided in classes when continuing your taste from one sample to the next.

We thank you very much for your kind cooperation.

Code	Color	Flavor	Taste	Overall Acceptability

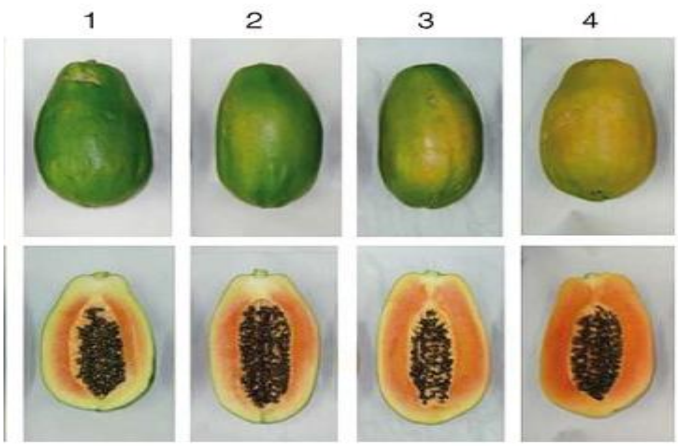
Score the samples based on the following ratings.

1-Dislike 2-Slightly dislike 3-Nor dislike nor like 4-Slightly like 5-Like

Comment ………………………………………………………………………………..

………………………………………………………………………………………

LIST OF FIGURES IN THE APPENDIX



Source: Adapted from Basulto *et al*. (2009)

Appendix Figure 1 Visual representative of papaya fruit at each maturity stage

Appendix Fig 2 Fresh papaya samples

Appendix Fig 3 Dried papaya samples

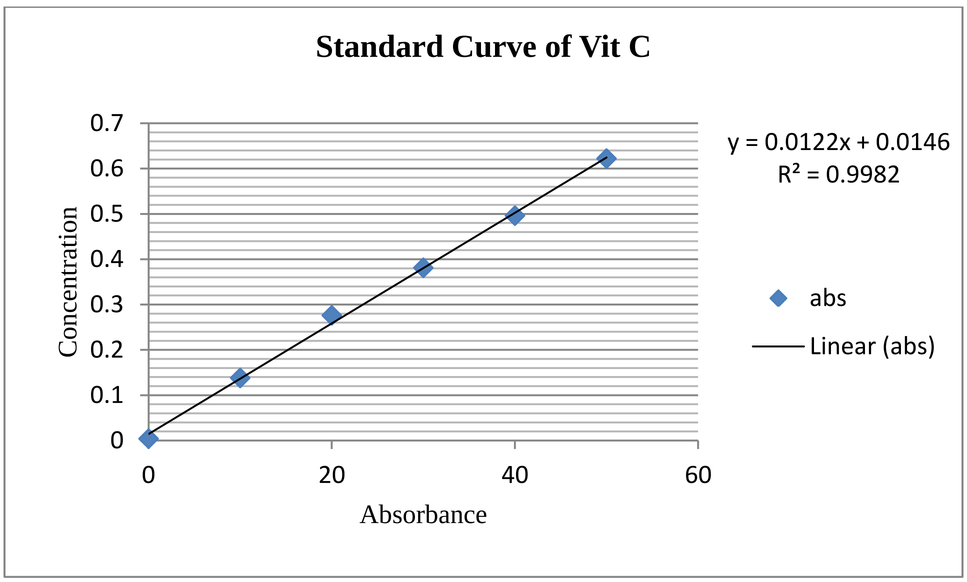
Appendix Figure 4 Titration of papaya

Appendix Figure 5 β-Carotene analysis

Appendix Figure 6 Protein analysis

Appendix Figure 7 Fiber analysis

Appendix Figure 8 Sensory analysis



Appendix Figure 9 Standard curve of vitamin C analysis