THE EFFECT OF BANANA POSITIONS WITHIN A BUNCH ON THE RIPENING BEHAVIOR OF *Musa acuminata* cv. BERANGAN

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THE EFFECT OF BANANA POSITIONS WITHIN A BUNCH ON THE RIPENING BEHAVIOR OF *Musa acuminata* cv. Berangan

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Research Report submitted in partial fulfillment of the requirements for the degree of Bachelor of Agrotechnology Science (Post Harvest Technology) under supervision of Miss Roshita Binti Ibrahim and co-supervisor Dr Adzemi Mat Arshad

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ENDORSEMENT

The project report entitled **The Effect of Banana Positions within a Bunch on the Ripening Behavior of *Musa acuminata* cv. Berangan** by **James Jam Anak Jolly** Matric Number **UK14747** has been reviewed and corrections have been made according to the recommendations by examiners. This project is submitted to the Department of Agrotechnology in partial fulfillment of the requirement of degree of Science in Agrotechnology (Post Harvest Technology) Faculty of Agrotechnology and Food Science, Universiti Malaysia Terengganu.

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DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been dully acknowledged.

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ABSTRACT

A study on the ripening behaviors between different position of hands (upper, middle and lower) within intact and de-handed bunches of 'Berangan' banana (*Musa acuminata*) was carried out. The ripening behaviors were determined based on quantitative measurements of physico-chemical characteristics during storage at ambient temperature of 3 days intervals for 12 days. Both intact and de-handed bunches of bananas had shown different patterns of ripening behaviors in terms of physical changes (peel and pulp color and weight ratio, fruit weight, texture and volume) and chemical changes (starch, total soluble solid (TSS) and tannins) with respect to different hand positions (upper, middle and lower). There were increasing trends of fruit volume, size, color (L, a, b) and TSS content whereas peel and pulp weight ratio, weight changes, peel and pulp texture, starch and tannin contents showed decreasing values over the storage. This study had proven that, maturation of fruits in a bunch started from upper hands down to lower hands in both intact and de-handed bunches of bananas. Nevertheless, the lower hands were able to catch up with the ripening process in terms of total soluble solid, tannins and starch contents where towards the end of storage day, their contents had synchronized with those upper and middle hands although upper and middle hands had showed advance changes in terms of physical characteristic (peel color) thus resulting in contemporaneous ripening within a bunch. Besides, this study also showed that ripening process occurred faster in de-handed bunches compared to the intact bunches of bananas.

ABSTRAK

Kajian tentang perbezaan perilaku kematangan antara kedudukan sikat (atas, tengah dan bawah) dalam setandan dan tandan yang telah pun diasingkan kepada sikat 'pisang Berangan' (Musa spp) telah dijalankan. Perilaku kematangan ditentukan berdasarkan pengukuran kuantitatif melihat kepada ciri-ciri fizik kimia sepanjang penyimpanan pada suhu bilik selama 12 hari dan data serta analisis dibuat selang 3 hari sekali. Kedua-dua pisang dalam setandan dan tandan yang telah diasingkan kepada sikat telah menunjukkan pola perilaku kematangan yang berbeza dalam perubahan fizikal (warna kulit dan isi buah dan nisbah berat, perubahan berat keseluruhan, tekstur dan isipadu) dan perubahan kimia (kanji, jumlah keseluruhan pepejal terlarut (TSS) dan tannin) pada kedudukan sikat yang berbeza (atas, tengah dan bawah). Peningkatan didapati dalam aspek isipadu buah, saiz, warna (L, a, b) dan kandungan TSS manakala nisbah berat kulit kepada isi, perubahan berat buah keseluruhan, kulit dan tekstur isi, kanji dan kandungan tannin menunjukkan penurunan nilai selama simpanan. Kajian ini juga telah membuktikan bahawa, kematangan buah dalam setandan bermula daripada sikat atas pada kedua-dua pisang dalam setandan dan tandan yang telah diasingkan kepada sikat. Namun demikian, sikat pada bahagian bawah mampu mengejar dan menyamaratakan proses pematangan dari aspek keseluruhan pepejal terlarut, tannin dan kandungan kanji, walaupun sikat bahagian tengah dan bahagian atas lebih awal menunjukkan perubahan dalam ciri-ciri fizikal seperti perubahan warna (kulit). Selain itu, kajian ini juga menunjukkan bahawa proses pematangan berlaku lebih cepat dalam tandan yang telah diasingkan kepada sikat berbanding dengan dalam setandan tanpa diasingkan kepada sikat.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Banana fruits have special place in human diets. They are chiefly eaten as desert fruit, at the ripe stage they are sweet and easily digestible (Robinson, 1996). They are useful for patients with peptic ulcers, for treatment of infant diarrhea (Kosler, 1959). They are low in fats, cholesterols and salts. (Ahmad et al., 2001). They can make useful contribution in the human diet in synthesizing the vitamin A, C and B6. Studies have been done regarding ripening behavior of fruits for 'Pisang Embul' (AAB), 'Pisang Kolikuttu' (AAB), 'Ash Plantain' (ABB) and Snake fruit (Weerasinghe and Ruwanpathirana, 2004). These include studies during pre-harvest as well as post-harvest. According to Abdullah et al., (1985) and Abd. Shukor et al., (1986), ripening behavior of fruits may be different with respect to its cultivar especially for banana fruits. So far, there is no study regarding ripening behavior of banana cultivar 'Pisang Berangan', within a bunch at different positions of intact and de-handed bunch of bananas.

According to Lassoudiere and Maubert, (1971) and Lassoudiere, (1972), there are variability in fruit size, weight and appearance of banana fruits exist within a bunch due to a negative gradient in fruit weight from the top (basal) to the bottom (distal) of the bunch. Fruit at the bottom of the bunch is 30 % to 40 % smaller than that at the top (Robinson, 1996) and this contribute to yield variability as the whole bunch is harvested at the same time. Therefore according to Munasque, (1979), due to size and weight variability, the upper hands within a bunch ripen first after harvested regardless its maturity index at harvest.

Most of de-handing techniques today only practiced during pre-harvest and is proven beneficial to farmers due to good quality of fruits produced, as been reported by Weerasinghe and Ruwanpathirana, (2004) and Jullein et al., (2000). According to Abdullah, (1986), the changes in terms of physico-chemical occur steadily as fruits ripen from index 1 to 7. It has been proven that the upper hand of bunch will show the symptoms of ripening such as peel color changes, size enlargement as well as chemical changes compare to the middle and lower hands. Therefore, according to this statement, we can assume that although a bunch of banana is de-handed, the process of ripening still occur from upper hand down to lower hand and followed by consistent physico-chemical changes from upper hand down to lower hand respectively.

1.2 Problem Statement

It is estimated that in the developing countries, more than 25 % of the fruits and vegetables produced are wasted due to poor postharvest quality. These wastages can be minimized or reduced if proper harvesting, handling and storage techniques are practiced or carried out properly. Since fresh produces contain live cells, they are sensitive to surround environment or atmosphere and gradually undergo physico-chemical changes with time. Each commodity has their own physiological characters and composition and each of them has a unique response to surrounding environment. Hence, problems have arisen and it has been found that fruits from different locations on the same bunch have different maturity and maturity index with respect to intact and de-handed bunch of banana.

1.3 Significant of Study

This research is aiming for economic importance as ripening behavior play vital roles in keeping and maintaining fruits quality. As for transport, bananas must be sound, clean, whole, fresh, free of foreign odors and taste, free of abnormal moisture and undamaged. The color of the fruits should correspond to ripeness grade 1. In addition, they must be free from rot and mechanical damage. The hands must be treated against comb or stalk rot with fungicidal paste. Besides, the size difference in between the second hand and the last hand is marginal and bunches are more uniform and more cylindrical in shape when de-handed (Weerasinghe and Ruwanpathirana, 2004). External appearance of the fruit is superior and alluring with de-handing, however appearance of the bunch is good only in cultivars that produce more number of hands. Other than that, de-handing also extends the green life of the fruits from 2 to 3 days depending on the cultivars (Weerasinghe and Ruwanpathirana, 2004).

This research also important where we can study the chronology and duration of fruit development phases in relation to their position on the bunch, which is beneficial to farmer where they can produce good quality banana thus high production of banana, is obtained. According to Jullien et al, (2001), the upper (basal) hands are in favored position in the photosynthetic pathway and consequently the growth of the lower fruits is limited by carbon supply. Therefore farmer may take actions to discard the bottom hand if the bottom hands are attacked by pests or diseases to produce good quality in the upper parts thus economically benefited during pre-harvest as well as post-harvest. In commercial practice, bananas are never allowed to ripen on the plant and bananas require ethylene treatment to induce ripening process (Mendoza, 1977).

1.4 Objectives

This study was carried out to investigate the ripening behavior of banana at different positions within a bunch of intact and de-handed bunches stored at ambient temperature. This is achieved with the determination of the following specific objectives.

1. Determination of the ripening behavior in terms of physico-chemical changes of banana at different positions within a bunch during storage at ambient temperature.

2. To compare the ripening behavior and quality of banana at different positions within a bunch of intact and de-handed bunches of banana.

CHAPTER 2

LITERATURE REVIEWS

2.1 Banana

The banana is one of the oldest cultivated plants in the world and the fourth most important food crop in the developing world (FAO, 1985). It is grown on commercial and non-commercial scales in the tropics and sub tropics. Banana is actually the common name for a type of fruit and also the herbaceous plants of the genus *Musa* which produce this commonly eaten fruit and world production of *Musa* in 2003 was estimated at 102 millions tons, of which about 68 % was classified as bananas and 32 % as plantains (FAO, 1985). Botanically, it is a berry, belonging to the Musaceae family. Originally from tropical Asia, it has become widespread throughout the tropical and subtropical regions of the earth (Jamaluddin and Pascua, 1986).

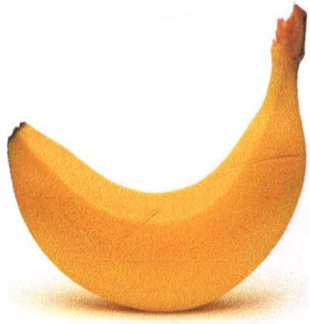
Although evidence suggests that banana could have originated from Malaysia, the development of bananas industries in Malaysia are still modest. In 1966, the total area for banana cultivation in West Malaysia is roughly 6082 hectares (FAMA., 1968). In recent years, banana cultivation in Malaysia has undergone fast growing industry with the joint support and involvement of few private associations and several government agencies in promoting as well as commercializing banana as a main fruit for export for both local and international markets. Bananas are likely to have been first domesticated in Papua New Guinea. Today, they are cultivated throughout the tropics involving around 107 countries where a banana often refers to its softness and sweetness "dessert' bananas (Gorrez, 1986). Some of the wild banana has numerous large and hard seeds whereas virtually all culinary bananas are seedless fruits. Basically, banana can be classified into four varieties namely dessert bananas, which are primarily eaten fresh (fleshy, sweet, soft and flavorsome) such as 'Pisang Embun' (AAA) , 'Pisang Rastali' (AAB) and 'Pisang Berangan' (AA), secondly as baby bananas, small variety of dessert banana example is 'Pisang Mas' (AA) , thirdly cooking bananas which can be eaten only after been cooked (mealy and starchy plantains) such as 'Pisang Tanduk' (AAB), 'Pisang Raja Pulut' (AAB), 'Pisang Nangka' (AAB), 'Pisang Siem' (ABB), and lastly fiber bananas which providing source of fibers (abaca and Manila hemp) examples are 'Pisang Berangan' (AA) and 'Pisang Rastali' (AAB). (Abdullah et al., 1986).

Banana is an English word which scientific name is *Musa paradisiaca.* In German it is called 'Bananen' whereas in French it is called 'Bananes' and 'platanos/Bananas' in Spanish. The banana plant develops a false trunk (pseudostem) composed of leaf sheaths, from the center of which there emerges the apical flower and fruit spike (Pantastico, 1979). For some species this pseudostem can reach a height of up to 2–8 m, with leaves of up to 3.5 m in length. Each pseudostem can produce a bunch of green bananas which when ripened often turn yellow or sometimes red. A variety was even recently discovered in a rainforest in Asia that turns purple (Pascua, 1986). This then dies and is replaced by another pseudostem. Banana which is very popular because of its high carbohydrate content (mainly as glucose) and also its aromatic taste and are harvested all year round (Israeli and Lahav, 1986).

Banana plantation area in Malaysia was estimated as 23,952 hectares in the year of 1984 and has increased to 35,449 hectares in the year of 1992 (F.A.M.A, 1986). The export of banana also reported have rose from 32,630 tonnes in 1984 to 37,169 tonnes in 1993. The main importers countries are Brunei, Hong Kong, Japan and Singapore and the new export destinations for Malaysia are South Korea (13.44

%) and Japan (14.05 %) started at the year of 1991. The estimated world production for bananas and plantains in 1987 was about 66 million tonnes and 40 million tonnes from the total production was amounted as banana alone. In 1989, banana was the thirteenth most popular fruit as admitted by Malaysians from Peninsular Malaysia. In the aspect of production, banana was the second highest total production after durian with rough yield of 200,148 which has contributed RM 1,853 million or 10 % to Gross National Production (GNP). Up to date, Malaysia has been ranged among 25 top countries producing bananas with total production of 535, 000 metric tonnes. As for world production, it is estimated that total world production is 55, 221, 871 metric tonnes with weighted average of 1, 150, 455.6 metric tones.

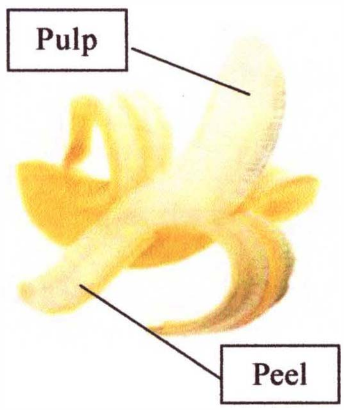
According to Munasque and Abdullah et al, 1987, the banana fruit grow in hanging clusters with up to 5 -7 fingers to a tier (called a *hand*) and 15 – 20 fingers tiers to a bunch (200 banana). The total of the hanging clusters is known as a bunch, or commercially as a "banana stem", and can weight from 30–50 kg. The fruit averages 125 g, of which approximately 75% is water and 25% dry matter content. Each individual fruit (known as a banana or 'finger') has a protective outer layer (a peel or skin) with a fleshy edible inner portion. The Figure 2.1 describes the terminologies used.

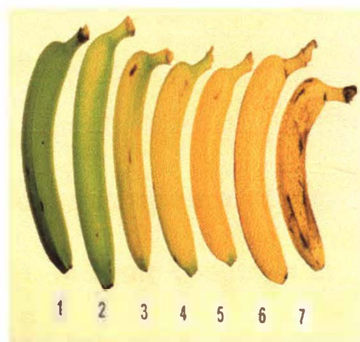


A bunch of banana

A finger of banana

A hand of banana





A cluster of banana

Finger diagram

Maturity Index

Figure 2.1: Terminologies used to describe bananas.

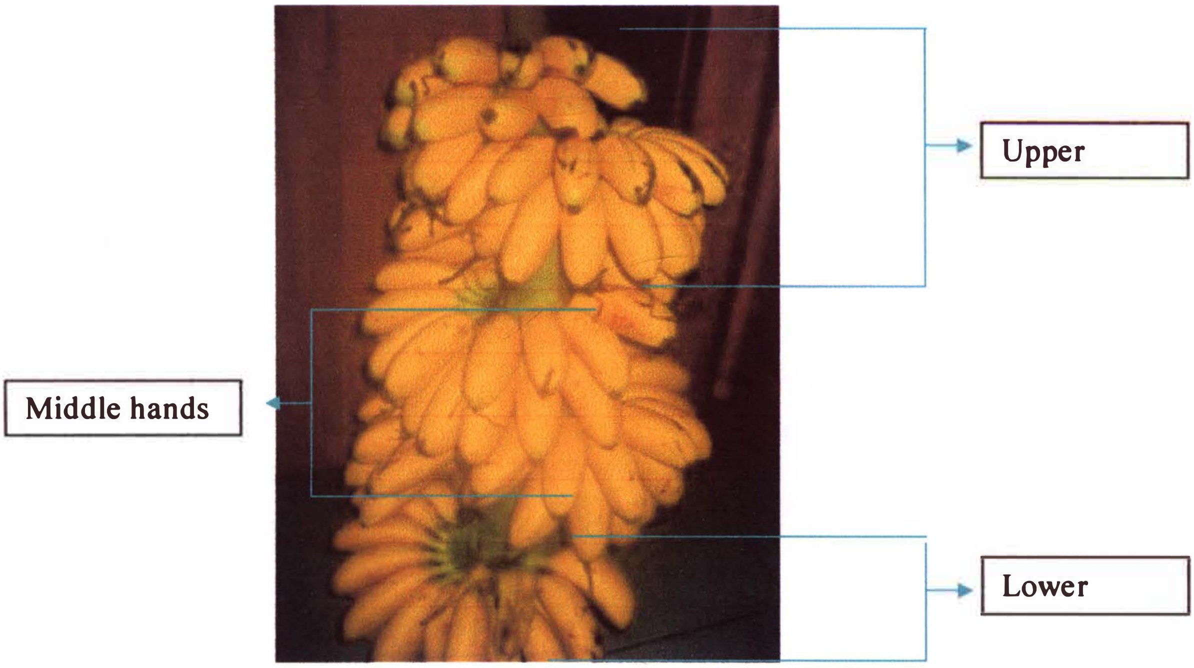


Figure 2.2: Parts in Bunch of Banana.

The banana heart also known as the male part which is single and sterile will be produced by each stem (Israeli and Lahav, 1986). In some countries in Southeast Asia, bananas hearts are consumed as salad and vegetable and eaten raw (Pascua, 1986). As for the female part where flowers are produced further upper part of the stem and actual fruit are produced without requiring fertilization and the fruits are described as a “leathery berry (Israeli and Lahav, 1986)”. Some sources assert that the genus of the banana, *Musa,* is named for Antonio Musa, a physician to the Emperor Augustus. Others say that Linnaeus, who gave the genus its name in 1750, simply adapted an Arabic word for banana, mauz. The word *banana* itself comes from the Arabic word banan, which means "finger" (Abd. Shukor et al., 1986 and Abdullah et al., 1985).

The maximum duration of storage of different types of bananas are summarized as in Table 2.1 and the controlled atmosphere storage as in Table 2.2.

Table 2.1

Designation	Temperature	Relative Humidity	Max. Duration of Storage
Cavendish-Robusta	12.5 – 12.8°C	95%	28 days
Bananas, General	13 – 15°C	80 - 95%	14 - 21 days
Green Bananas	13°C	90 - 95%	14 - 21 days
Yellow Bananas	13°C	90 - 95%	3 - 6 days

Table 2.2

Temperature	Relative Humidity	O_2	CO_2	Suitable for Controlled Atmosphere
13.9 - 15.6°C	85 - 95%	2 - 5%	2 - 5%	Very good

According to Abdullah et al., (1986), most edible bananas originated from two species in the genus Musa, *M. acuminata* and *M. balbisiana*. The cultivars are either hybrids among subspecies of *M. acuminata* or between *M. acuminata* and *M. balbisiana*. These hybrids are diploid (two sets of chromosomes), triploid (three sets, the most common and important ploidy), or tetraploid (four sets). A perceptive observer can usually deduce a variety's genome (i.e., its ploidy and relative content from *M. acumniata* and *M. balbisiana*) by observing leaf thickness, size, and orientation, and by using a scoring system that considers 15 morphological characteristics (Jamaluddin, 1986 and Valmayor et al., 1981). However, ploidy is best determined by chromosome counts or flow cytometry (Balaguru et al., 1987). These include pseudostem ("trunk") color, leaf stem (petiole) structure, fruit stalk (peduncle) hairiness, shape and size of the male bud, scars left from falling flowers on the lower fruit stalk (rachis), and details of the male flowers. When denoting each cultivar's genome, a lettering system is used. For example, *M. acuminata* and *M. balbisiana* are diploids, with genome AA and BB, respectively, and AA and AB clones are cultivated. Hybrid triploids are classified as AAA, AAB, or ABB. Tetraploid bananas may be AAAA, AAAB, AABB, or ABBB. *M. acuminata* evolved primarily in tropical rainforests in Southeast Asia, whereas *M. balbisiana* originated in monsoon areas in northern Southeast Asia, and southern Asia (Jamaluddin, 1986; Valmoyor et al., 1981 and PCARRD, 1988). Thus, pure *M.* acuminata cultivars developed first in Southeast Asia and its hybrids with *M. balbisiana* arose where distributions of the two species overlapped (Pascua, 1986 and FAO, 1985).

Along with other fruits and vegetables, consumption of bananas is associated with a reduced risk of colorectal cancer and in women, breast cancer and renal cell carcinoma. Individuals with a latex allergy may experience a reaction to bananas. The juice extract prepared from the tender core treats kidney stones and high blood pressure. Bananas contain considerable amounts of vitamin B_6, vitamin C, and potassium. The latter makes them of particular interest to athletes who use them to quickly replenish their electrolytes.

2.2 De-handing of Banana Bunch

A number of cultural measures are being adopted and taken into consideration to increase the quality of banana especially the fruit size. Bunch trimming or de-handing is one of the measures use to enhance the fruit size and the yield over the world. Removal of incomplete hands soon after bloom is reported to increase the weight of remaining hands (Samson, 1980). Simmonds (1962) reported that intra bunch competition reflects an inverse relationship between fruit size and growth rate of fruits. Daniells and Bryde (1995) observed an increase in bronzing of banana fruits, and reduction in bunch weight at maturity and low profit per bunch due to de-handing.

Later, Daniells and Foster (2001) observed a 12 % reduction in a bunch weight and improvement of green life of fruits due to bunch trimming in banana. The size difference between the upper hands and the bottom hands are marginal and bunch are more uniform and more cylindrical in shape and size when de-handing is done. De-handing resulted in a more homogenous size and alluring fruits when compared to handed banana (Weerasinghe and Ruwanpathirana, 2004). De-handed bunches are more or less cylindrical and look perfect at glance whereas handed bunches are slightly conical in shape and less perfect. However, cultivars which posses a fewer number of hands in a bunch give a bulge appearance to the bunch though the individual hands are attractive (Weerasinghe and Ruwanpathirana, 2004). Therefore, de-handing technique can be practiced to improve the fruit size and the market price of banana by considering the stage of maturity at harvest when applying the de-handing techniques since fruit splitting can occur due to over-ripening (Weerasinghe and Ruwanpathirana, 2004).

2.3 Ripening Behavior in a Bunch of Banana

Fruit ripening processes can be determined and observed through physico-chemical changes in terms of peel and pulp color, starch and pectin contents and total soluble solid (TSS) that occurred in the fruits (Samson 1980). Fruits can be classified into two categories which are climacteric fruits such as apple, banana and papaya, whereas non-climacteric fruits are citrus fruits and durian. The climacteric fruits are not only an upsurge in respiratory activity, but also physical, chemical, physiological and metabolic changes associated with this increase in respiratory rate (Rhodes, 1970). Climacteric fruits generally reach the fully ripe stage after the respiratory climacteric and non-climacteric fruits show a steady downward drift in respiration and relatively show changes in the various ripening parameters (Biale and Young, 1954). Fruits are harvested at different maturity stages depending on export and local market requirements and also transport. Bananas are an extremely perishable commodity and the application of refrigeration of green banana tends to reduce the level of respiration. Ripening of banana is initiated by exposing it to 1000 ppm ethylene (C_2H_4) gas for 24 hours at 20°C or lower (Inaba and Nakamura, 1986). According to Weerasinghe and Ruwanpathirana, 2004, ripening behavior refers to how fruit ripens, where it starts to ripen, how the pattern of changes and what are the processes involved which include physical and chemical changes.

Table 2.3: Changes that may occur during Ripening of Fruit (Biale and Young, 1954)

Degradation	Synthetic
Destruction of chloroplast	Maintenance of mitochondrial structure
Chlorophyll breakdown	Carotenoids and anthocyanins formation
Destruction of acids	Increase TCA cycle activity
Starch hydrolysis	Interconversion of sugar
Oxidation of substrate	Increased ATP generation
Inactivation by phenolic compound	Synthesis of flavors volatiles
Solubilization of pectin	Increased amino acid incorporation
Activation of hydrolytic enzymes	Increased transcription and translation
Initiation of membrane leakage	Preservation of selective membrane
Ethylene induced cell wall softening	Formation of ethylene pathways.

2.4 Fruit Growth and Maturation of Banana

According to Munasque et al., (1990), the initiation of the fruit bud in the plant starts the life of a banana fruit. The fruit then undergoes four phases of development, namely growth, maturation, ripening and lastly is senescence. The growth stage is characterized by rapid cell division and elongation. Maturation is marked by physical and chemical changes that have bearings on fruit quality and post harvest behavior. It overlaps with the growth stage and terminates with ripening during which the fruits develop the flavor, texture and aroma for optimum eating quality (Wills et al., 1989). The ripening process is further characterized by the increased rate of respiration and ethylene production followed by a decline which signals the onset of senescence (Bautista and Esguerra, 1982).

2.5 Pre-Harvest Factors Affecting Fruit Quality

The quality of banana is the result of the conditions and treatments that the fruit experienced not only after harvest but also during its growth and development (Munasque et al., 1990). These pre harvest factors have influenced the quality of banana during post harvest. Therefore the effect of each pre harvest condition or treatment can be identified and observed through climacteric and cultural factors.

2.5.1 Climatic Factors

Light and relative humidity have been implicated in the different behavior of 'Cavendish" bananas after harvest (Gelido, 1986). Fruits that developed under full shade posses a dull yellow peel color, whereas under partial shade, the peel of the ripe fruit is bright yellow (Munasque et al., 1990. This fruits response is reminiscent of a light-mediated synthesis of carotenoid pigments and under low light intensity, the development of the carotenoid pigments, which are unmasked during ripening is retarded (Pantastico and Mendoza, 1970). In addition to the above, high relative humidity during development resulting in short storage life, high incidence of finger drop and crown rotting of the fruits.

2.5.2 Cultural Factors

Minerals nutrients, irrigation, fruit bagging and thinning are major factors affecting the quality of bananas during and after harvest. Mineral nutrients affecting bananas quality in varying degrees. High potassium and calcium levels are associated with increased dry matter and glucose contents in both the peel and both the pulp of "Cavendish' banana (Gelido, 1986). Besides that, low levels of nitrogen, phosphorous and magnesium are associated with high dry matter content in the pulp of fruits and similarly in ripe fruits, increased level of phosphorous results in low levels of total sugars, while high magnesium content in the peel associated with increased incidence of neck breakage, also known as finger drop or weak neck. (Munasque et al., 1990).

Adequate irrigation plays a vital role in overall growth of plant and producing good quality of banana in order to avoid the incidence of physiological disorders of banana after harvest. It has been reported that banana from non-irrigated areas are susceptible to the green ripe disorder. Furthermore, fruits obtained from diseased plants (Sigatoka – infected plants) have poor harvest quality manifested by slight yellowing of pulp although externally unripe (Bautista and Esguerra, 1982).

Fruit bagging is purposely for export banana or for international markets practiced in banana plantations. This is to avoid non-uniform quality as well as the poor appearance of banana caused by pest or disease attacked. Bagging is done when all fruit hands are out for about 8-12 hands per bunch for "Cavendish" banana (Gelido, 1986). In "Lakatan" bananas, allowing 5 – 7 fruit hands to develop in a bunch would end up with all the fruits growing into the "Large" size category (Boncato, 1967). The polyethylenes bags are perforated and are sometimes are impregnated with pesticide.

2.6 Respiration and Ethylene Production in Banana

According to Acedo and Bautista 1989, banana fruits inhibit a climacteric pattern of respiration, characterized by an initially low rate of carbon dioxide production or oxygen uptake (preclimacteric), followed by a sudden upsurge (climacteric rise), a leveling-off (climacteric peak) and finally a decline (post climacteric) and the same thing also applies for ethylene production. Therefore, the storage life or the green life of banana is determined by the preclimacteric period and the preclimacteric period in bananas and the factors affecting it have been well reviewed by Marriot, 1980.

The involvement of 1-aminocyclopropane-1-carbocylic acid (ACC) in ethylene biosynthesis of 'Cardaba" banana after harvest was studied by Lizada et al., 1983. During preclimacteric, the ACC contents were low and ACC contents increased markedly with the climacteric rise. (Abdullah, 1987). In "Saba" banana, the rise of ethylene production during climacteric was preceded by the rise in ACC content of the pulp (Acedo and Bautista, 1989). The ACC levels reached its peak as the rate of ethylene evolution was rising and they dropped and the observation was made by Hoffman and Yang (1980) on avocado, banana and tomato.

The preclimacteric period is an inverse linear function of temperature and the nature of the climacteric however, differs among varieties. (Marriot, 1980). The "Kluai Khai", for example, relatively shorter number of days to reach the peak compared to other varieties at all temperatures, which may also indicate its relatively poor storage performance (Abdullah et al., 1987).

Maturity at harvest plays an important role in respiratory behavior of banana. 'Pisang Mas" harvested 9 weeks after pollination displays and upsurge in carbon dioxide and ethylene production within a day after harvest while 6 - 8 week old fruits have been extended preclimacteric period for at least a week. (Nair and Tung, 1988).

It has also been reported that "Lakatan" bananas at the "Light full three quarters" maturity remain preclimacteric during a 3 week storage at 23 °C, whereas the "full" fruits attain the climacteric after 7 days storage (Mendoza, 1968). Similarly in "Cavendish" banana the preclimacteric period is prolonged in less matured green fruits (Inaba et al., 1984). Fruits harvested 65-75 days after flowering have more than 10 days of green life, while those harvested at 85-95 days after flowering have less than 4 days (Inaba et al., 1984). In "Kluai Hom Thong", the preclimacteric periods for fruits harvested at 65-70 %, 75-80 % and 85 % maturity are 49, 39 and 9 days respectively at 25 °C (Tongdee, 1988).

2.7 Post-Harvest Handling of Banana

2.7.1 Storage Method

2.7.1.1 Refrigeration

The preclimacteric period is prolonged by the decreased in the temperature (Abdullah et al., 1987). Investigations on the effect of temperature show that, over a small range of temperature, close to the optimum for storage. 12.5 °C to 21.5°C, the preclimacteric period is an inverse linear function of temperature with temperature coefficients in the range 1 to 3 days per 1°C (Peacock and Blake, 1970).

Generally the optimum storage for most ASEAN banana cultivars is in the region of 13 to 14 °C at relative humidity between 85-95 %. The optimum temperature for most Philippine bananas is 13 °C (Pantastico and Mendoza, 1970). The same temperature also found to be suitable for "Kluai Khai", "Kluai Namwa", and "Kluai Hom Thong" from Thailand. However for most Malaysian cultivars including "Pisang

Mas", "Pisang Rastali", and "Pisang Embun", a storage temperature of 14 °C is recommended.

2.7.2 Post-Harvest Treatment to Extended Shelf life of Banana

2.7.2.1 Surface Coating

The purpose of waxing is to extend the shelf life of bananas. Application of a thin film of natural or artificial wax on the fruit surface reduces transpiration and consequently, minimizes desiccation and shriveling (Pantastico et al., 1975). It also reduces respiration rate and enhances the visual quality of the fruits. "Saba" bananas coated with a commercially available wax formulation, Decco Lustre 2002, show a lower rate of ripening relative to unwaxed fruits (Pastor and Pantastico, 1984). Other commercial waxes like "Carbowax" and 'Prima Fresh" are not effective in prolonging the storage life of the "Saba' fruits (Paderon, 1984).In "Cavendish" bananas ripening process is delayed by 1.5 % using PL-80 or prolong (Formulated from sucrose fatty acid esters) (Lizada and Novenario, 1983).In a commercial treatment trial, Prolonged reduced the incidence of green ripe disorder of the fruits (Scott et al, 1983).

Coating bananas with TAL Pro-long modified their internal atmospheres by reducing the permeability of the fruit skin to gases. Permeability of control fruit to carbon dioxide was greater than that to oxygen and ethylene, and this differential permeability was enhanced by coating. This resulted in a depression of the fruit's internal oxygen content which affected ripening without a concomitant increase in the levels of carbon dioxide which could have proved toxic. The skins of coated fruit lost chlorophyll more slowly than controls and there was a small effect on the accumulation of monosaccharides in the fruit pulp. These effects were associated with depressed rates of respiration and ethylene production in the coated fruit, but the accumulation of acetaldehyde and ethanol was no more rapid than in controls

2.7.2.2 Moist Sawdust

Storage in sawdust has been shown to extend markedly the storage life of "Saba" bananas (Uy and Lizada, 1984). By comparison to control bananas, bananas stored in sawdust has lower rate of peel color changes. Ripening in sawdust-stored fruits proceeds normally albeit at a reduced rate. Sawdust-stored fruits show comparable firmness to that of control fruits with the same color index but shorter storage period, and were highly marketable (Abdullah, 1987).

2.7.2.3 Irradiation

Generally, irradiation has slower down the ripening process thus resulting in extended the shelf life of fresh banana. They are few factors that influence the response of banana towards irradiation namely cultivar, stage of maturity and irradiation type as well as dosage (Balaguru et al., 1987). In "dwarf Cavendish" cultivar ultraviolet treatment markedly delay ripening of matured fruits. However, excessive expose to UV irradiation induces peel browning in bananas particularly when the fruits are kept in the dark (Tan, 1988).

A more common radiation type, gamma radiation has been found to delay ripening process of "Latundan" without adverse effects on the organoleptic quality (Manalo et al., 1968; Rillo, 1968). A dose of 25 to 50 Krads are recommended to banana at maturity stage of 3 to 4. The shelf life of banana will be extended 25 % to 35 % respectively, relative to unirradiated fruits. The irradiated fruits have comparable physical and chemical changes and organoleptic properties as the untreated fruits.

Such irradiation treatment even increased the ascorbic acid content of the fruits while a higher dose caused a decreased. For "Pisang Mas", a dose of 10 Krads was found to be optimum for storage life extension. The fruits ripened fully only after 11 days compared to 7 days for controls (Balaguru et al., 1987).

2.8 Changes during Ripening in Banana

2.8.1 Color Changes

Banana peel yellowing is due primarily to chlorophyll breakdown (Montenegro, 1988). According to Lizada et al., 1983, the chlorophyll content decrease slowly with ripening and generally, a certain amount of the green pigment remains in the fruit especially in the internal tissues. Therefore, the degradation of chlorophyll as been ascribed to chlorophyllase action.

The loss of chlorophyll pigments reveals the carotenoid pigments where there is no net carotenoids synthesis during ripening process. The peel carotenoids consist mainly of α- carotene, β- carotene and lutein occurring at concentrations ranging from 5 to 10 μg/ g fresh weight (Gross et al., 1976; Montenegro, 1988). Carotenoid levels did not vary according to maturity indexes as what happen to chlorophyll levels. Therefore, full potential of carotenoids synthesis in the peel is well achieved before green mature stage. (Lizada et al., 1983).

According to Abd. Shukor et al., (1986), there is a certain range of fruits maturity at harvest within which the fruits show comparable ripening behavior. Examples are comparable peel color changes with ripening in 'Latundan' bananas harvested at 11-13 weeks after flowering and 'Lakatan' fruits harvested at 11-14 weeks after flowering (Montenegro, 1988; Artes and Lizada, 1988 and Munasque, 1987).

2.8.2 Texture Changes

Banana fruits soften gradually as ripening process taking place. It is primarily influenced by physical and chemical attributes such as starch and sugar content, peel thickness and its volume. The fruits of "Cavendish" and "Saba" have thicker peel which may explain their greater firmness than the 'Latundan' (Lizada and Novenario, 1983; Montenegro, 1988; Biglete and Bautista, 1987). Softening of banana is due to the solubilization of pectic substances in the cell wall and middle lamella. Increased levels of water soluble-pectin's are observed with advancing ripening in 'Saba' banana (Rivera, 1969). This indicates that polygalacturonase (PG) and pectin methyl estherase (PME) were involved in pectin breakdown processes. However the existence of these processes in banana has not been established (Tucker at el., 1990).

According to Madamba et al., (1977), softening of banana fruits is primarily due to the breakdown of starch and other non-pectic polysaccharide in the pulp where starch imparts cellular rigidity is converted to sugars during ripening process. Textural properties of ripen bananas is correlated well with their peel color and suggested as a simple physical texture measurement during bulk storage (Ramaswamy and Tung, 1989). Firmness of banana is closely related to reducing sugar and starch content during ripening at 60 °C (15.6 °C) (Finney et al., 1967). In contrast, bananas ripened at 16 °C and 25 °C result in firmer texture compared to those bananas ripened at 18 °C and 19 °C.

As for pectin, pectin is a polysaccharide substances found in higher tissues mainly deposited in the cell wall and middle lamella, acting as a cementing materials and derivatives of polygalacturonic acids and occur in the form of protopectin, pectinic acids, pectin and pectic acids (Kertesz, 1938). Pectic substances play vital role in maturation, softening and textural changes in some fruits (Pilnik and Voragen, 1970). Ripening and maturation process are involved in the breakdown of these compounds to sugars and acids (Doesburg, 1973). In United States of America, commercial pectin is commonly produced from citrus peel and apple pomace (Rause, 1967), and from other fruits such as guava (Von Loesecke, 1930). As banana ripens, the contents of soluble pectates and pectinates increase while the total pectin substances decrease (Von Loesecke, 1950) gradually and these reactions or changes are believed to be inversely proportional.

2.8.3 Flavor Development

Flavor is the sensation produced by a material taken in the mouth, perceived principally by the senses of taste and smell, and also by the general pain, tactile, and temperature receptors in the mouth. Flavor also denotes the sum of the characteristics of the material which produces that sensation. Flavor is one of the three main sensory properties which are decisive in the selection, acceptance, and ingestion of a food.

According to Charles et al., (1973), flavor is subtle and complex perception combining taste, smell and mouth feel. Ripening usually bring about an increase in simple sugars to give sweetness, decrease in organic acids and phenolics to minimize astringency and increase in volatile emanations to give the characteristics flavor of the fruits (Pantastico, 1975). Volatile flavors developed in most food plants mainly at the ripening stage - the result of plant metabolism through enzymatic reaction. In enzymatic reaction, processed banana will produced no fresh banana flavor nevertheless fresh banana produced fresh banana flavor due to the enzyme extracted from the peel.

2.8.4 Sugar Accumulation

The increase of sugar content in banana is due to the increase of starch hydrolysis during ripening process. Starch is a major component in the pulp of unripe banana comprising for about 15-25% in the table or dessert varieties and about 30-40% in cooking cultivars. During ripening starch is break down to sugar resulting in 15-30% sugar enrichment in the ripe pulp. According to Charles et al., (1973), there is no clear distinction in sugar content between table and cooking cultivars. The ripe table bananas have distinctly lower residual starch content (less than 5%) relative to that of cooking cultivars (more than 10%) (Madamba et al., 1977). In 'Lakatan' bananas, the onset of starch hydrolysis, sugar accumulation and TSS increase is earlier in more mature fruits than in less mature ones (Madamba et al., 1977). The same thing goes to 'Latundan' fruits. (Montenegro, 1988). The major contents present in the pulp of banana are sucrose, glucose and fructose (Von Loesecke, 1950). The total sugar and reducing sugar contents for green banana of index 1 are 1.32 % and 0.52 % and for banana grade 7 are 19.7 % and 10.3 % respectively.

Sucrose is the major component in contributing the amount of sugar present in fruits and an increased occurred early during ripening process and reached maximum level about 11 % when fruits are fully ripen or firm. As for glucose, it is always present at a slightly higher than fructose but both are coherent and continuously increase during ripening process occur and to be maximal in fully ripen banana for about 3 - 4 % respectively (Will et al., 1983).

2.8.5 Organic Acids and Phenolics

Organic acids are important in giving a desirable sugar to acid balance which results in a pleasing fruit taste after ripening (Montenegro, 1988; Artes and Lizada, 1988 and Munasque, 1987). During ripening process there will be markedly increased in titratable acids resulting in a drop of pH. Malic acid is a major organic acid constituent in banana. This along with citric acid increases with ripening. The changes in pH during fruits maturation are irregular, such that acidity level did not correspond towards or related to maturity index such as "Basrai" (Singh et al., 1976) and in "Embun" (Abdullah et al., 1985).

A sharp and a sudden increased in the level of acidity was recorded at week 11th and week 12th and a declined level of acidity was recorded at week 14th , after which the level of acidity keep on fluctuate with a range of 5.7 – 5-9 (Singh et al., 1976 and Abdullah et al., 1985). The highest pH value was recorded at week 12th for "Embun" (Abdullah et al., 1985) and also "Berangan" (Abdullah et al., 1987). These results indicated that, pH and titratable acidity (TA) in banana contents are not possible for correlation (Abdullah et al., 1987). The phenolics such as tannins, undergoes polymerization forming insoluble compounds and this result in loss or decrease of astringency in the ripe fruit (Madamba, 1977).

Tannin is one of the polyphenols which contribute to astringency taste in fruits (Swain, 1962, Goldstein and Swain, 1963, Joslyn and Goldstein, 1964, Ranganna, 1977, Ismail and Embong, 1984). Banana becomes astringent when in green or immature particularly during early stages of ripening (Von Loesecke, 1949). It is believed that decrease in astringency has correlated to decrease in tannin content in banana (Slocum, 1933).

During ripening of many edibles fruits, both tannin and astringency are reduced rapidly and the changes in astringency level are actually the reflection of changes that have occurred in the molecular size of tannins (Goldstein and Swain, 1963). Physiology of the astringency sensation was due to the interaction of these polyphenols with salivary proteins and glycoprotein (Goldstein and Swain, 1963, Aw and Swanson, 1985). Effects of tannin on browning in fruit and fruit products and cloudiness in fruit juices (Cash et al., 1976) have long been recognized.

2.8.6 Production of Volatiles

The present of aroma in ripe banana is primarily due to the production of complex mixture of volatiles. There are about 350 individual volatiles constituents contained in banana fruits. According to Abdullah et al., (1987) and Abd. Shukor et al., (1986), the increase in synthesis of the volatiles constituents generally commences late in the climacteric relative to the respiratory rise, starch to sugar conversion and tissue softening. Among the volatiles components, the acetate and butyrate esters account for about 70 % in ripe bananas (Tressl and Drawert, 1973)

2.8.7 Moisture Loss

The changes of water status have result in change in pulp to peel ratio during ripening process of banana. The ratio increase with ripening, the magnitude of which is higher in cultivars with thinner peel (Montenegro, 1988; Acedo and Bautista, 1989). The rise in peel to pulp ratio is related to sugar concentration in two tissues (Charles and Tung, 1973; Lustre et al., 1976). There is a more rapid increased in sugars in the pulp during ripening compared with that in the peel contributing to a differential change in the osmotic pressure. Water is withdrawn from the skin to the pulp, and pulp to peel ratio changes accordingly. Thus, water loss from the peel is driven by transpirational and osmotic forces. Consequently, water content decreases in the peel but not in the pulp during ripening (Suyanti and Dasuki, 1988).

2.8.8 Fruit Senescence

According to Lizada et al., 1983, fruit senescence in banana can be defined as the stage of decreasing synthetic but increasing catabolic activity which may coincide with the post climacteric decline. It can be observed and determined through the present of brown flecks or spots on the peel. The spots will spread to various parts of the peel and then coalesce. Abd. Shukor et al., 1986 reports that, senescent process may include further solubilization of pectic substances and dominant sugar breakdown thereby impart a certain 'acid taste' in the overripe bananas. The psychogenic nature of this change has been confirmed by the negative results of pathological studies (Vivencio, 1974).

The beginning of senescence is marked by the climacteric peak in banana. Miem, 1980, reports that the climacteric in 'Bungulan' banana degreened with 1000 ppm ethrel, occurs when the peel attains color index 5.5. Senescent spots are only observed when the peel attains color index 6. However, Ng and Mendoza 1980 observe that the appearance of spot in the same banana cultivar begins usually as the peel attains color index 3.5 to 4 which indicates that the senescent process may occur even when the fruits have not fully ripened.

CHAPTER 3

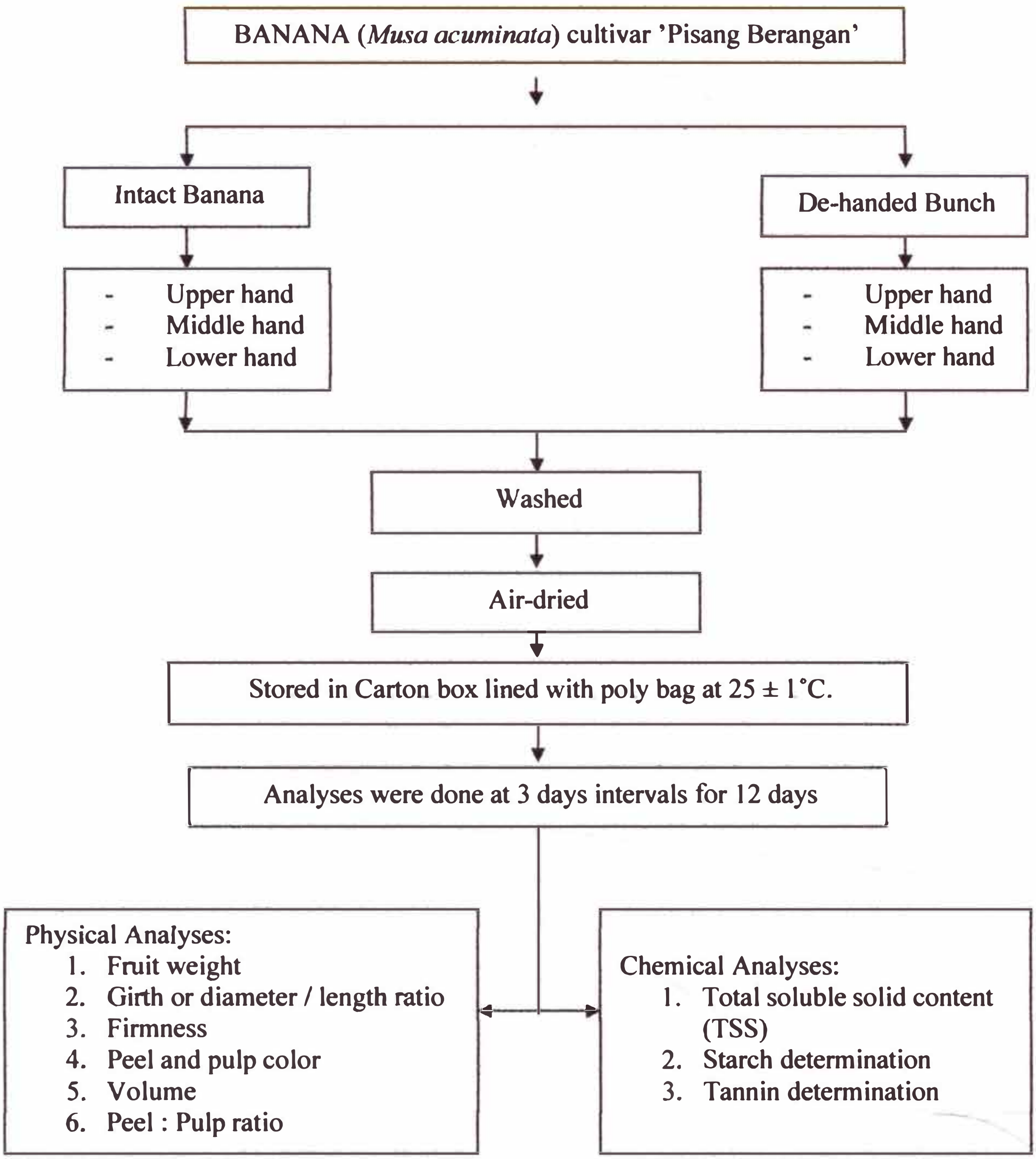
MATERIALS AND METHODS

3.1 Fruit Source and Sample Preparations

Banana fruits (*Musa acuminata*) var. Berangan were purchased from a local market. Fruits were harvested at maturity stage of 1 and were selected based on uniformity of size, the absence of physical damage and fungal infection and 100 % of the surface showing green color.

Commonly grown banana cultivar of "Pisang Berangan" (*Musa acuminata*) was selected for this experiment. Eight bearing hands of (banana) *Musa acuminata*, were selected at the maturity stage 1. Out of eight bunches of banana, three bunches were considered as controls where banana bunches were allowed to developed without de-handing. The remaining three other bunches were subjected to de-handing treatments by removing the first top hand, middle hand and the last bottom hand and the other two bunches were as control for observation. Then bananas were washed with tab water and air-dried. Experiment was run for two weeks where chemical and physical analyses were done at three day intervals (Day 0, 3, 6, 9, and 12) at ambient temperature. Intact and de-handed bunches of banana was placed in Carton boxes lined with poly bags. Stages of maturation of the fruits were followed in the Laboratory at ambient temperature of 25 ± 1°C. The experiment was done in three replicates where three fingers of banana were taken out to be analyzed from each bunch in term of its physical and chemical analyses.

3.2 Flow Diagram



3.3 Experimental Design

Experimental design used for this study was Randomized Complete Block Design (RCBD) and the number of replicates for every analysis was summarized in the table below.

X – Represents hand.
X^1 – Represents one finger is taken for analyses from each hand.

TREATMENT / PARAMETER	INTACT BUNCH			DE-HANDED BUNCH		
	UPPER	MIDDLE	LOWER	UPPER	MIDDLE	LOWER
Physical Analyses						
Fruit Weight	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$
Fruit Size	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$
Firmness	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$
Peel and Pulp Color	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$
Volume	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$
Peel and Pulp Ratio	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$
Chemical Analyses						
TSS	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$
Starch Content	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$
Tannin Content	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$	$X^1X^1X^1$

3.4 Physical Analysis

3.4.1 Fruit Weight

Bananas were weighted at the beginning of the experiment and every 3 day intervals using (Top Pan Balance Weight Shimadzu). Percentage weight loss was calculated based on the equation below. Three bunches of bananas corresponding to each treatment were used and the experiment was performed in triplicate (three fingers of bananas for each bunch).

$$\text{Weight Loss} = \frac{\text{Initial Weight (Day 0)} - \text{Final Weight (Day n)}}{\text{Initial Weight (Day 0)}} \times 100$$

3.4.2 Firmness

Firmness was measured as the maximum penetration force (g) reach during tissue breakage. Texture analyzer was calibrated with probe P/2N Stainless Needle for bananas and 4.0 cm height of bananas was estimated and calibrated with 35 mm return distances. The penetration depth was 5 mm and the pre test speed is 1.00 mm s^{-1} , test speed is 0.50 mm s^{-1} and post test speed is 5.00 mm s^{-1} measured using Stable Micro Systems, TA-XTplus Analyzer. Banana was measured at three locations (basal, middle and apical parts). Banana firmness value was an average of nine readings,

3.4.3 Peel and Pulp Color

Peel and pulp color have been evaluated using Konica Minolta Chromameter (Model Cr 400 Trimulus Color Analyzer). The coordinates were measured at three random locations on peel and pulp of banana. L^* is lightness, a^* (-greenness to +redness) and, b^* (-blueness to +yellowness) were the chromaticity coordinates. The a^* and b^* values were converted to chroma ($C = (a^{*2} + b^{*2})^{1/2}$) and hue angle ($h = \tan^{-1} (a^* / b^*)$). Three readings were taken at different locations on each banana pulp and peel for three fingers of bananas at different position

3.4.4 Peel and Pulp Ratio

As for peel and pulp ratio, each finger of banana from upper, middle and bottom hands were weighted and compared its weight in terms of its pulp and peel using Top Pan Balance Weight (Shimadzu). Measurements were done in triplicate for each different position.

3.4.5 Volume

As for volume, 1000 ml or 1 liter of measuring cylinder was needed. In order to evaluate its volume, 1000 ml of measuring cylinder was filled with 100 ml of water. A finger of banana was immersed in the measuring cylinder that was filled with 100 ml of water. The volume was obtained by subtracting final volume reading after a finger of banana was immersed in the measuring cylinder. Measurements were done in triplicate for each different banana positions.

3.4.6 Girth or Diameter to Length Ratio

Girth or diameter and length of a finger of banana were measured by using thread and ruler. This was due to the surfaces of a finger banana sometimes were not uniform in size therefore the use of thread helped in getting accurate reading of girth or diameter and length of a banana finger. Thus, this enables the diameter or girth over length ratio to be obtained precisely. Measurements were done in triplicate for each treatment.

3.5 Chemical Analyses

3.5.1 Total Soluble Solid Content (TSS)

The total soluble solid content (TSS) of the juice of banana flesh, which was obtained by squeezing the mashed banana through a muslin cloth and was determined using handheld refractometer at ambient temperature and expressed as a percentage. Measurements were done in triplicate.

3.5.2 Starch Determination

As for starch determination, we were using iodine solution in potassium iodide as a parameter to measure the percentage of starch present. A finger of banana was cut into two parts and one part was dipped into iodine solution and held for approximately 20 seconds in order to allowed iodine solution to be absorbed by banana's flesh. The higher the percentage of starch present, thus the higher the iodine solution absorbed and it can be seen through the present of blue black color on banana's flesh. The present of starch was expressed in percentage and measurements were done in triplicate.

3.5.3 Determination of Tannin

Estimation of tannins was carried out by using colorimetric method.

1) Colorimetric Method

Colorimetric estimation of tannins was based on the measurement of blue color formed by the reduction of phosphotungstomolybdic acid by tannin like compounds in alkaline solution.

2) Reagents:

I. Folin-Denis reagent:

750 ml of water was added to 100 g of sodium tungstate ($Na_2WO_2 .2H_2O$), 20 g of phosphomolybdic acid and 50 ml of 85 5 phosphoric acid. The mixture was refluxed for 2 hours, cooled to 25 °C and diluted to 1000 ml with water.

II. Saturated sodium carbonate solution:

100 ml of water was added to 35 g of anhydrous sodium carbonate, dissolved at 70-80 °C and cooled overnight. The clear liquid was decanted before use.

III. Tannic acid standard solution:

100 mg of tannic acid was dissolved in 1 liter of water. Fresh solution for each determination was prepared (1 ml = 0.1 mg of tannic acid).

3) Procedures:

I.) Preparation of standard curve

0 to 10 ml aliquots of the standard tannic acid solution was pipetted into 100 ml volumetric flasks containing 75 ml of water. 5 ml Folin-Denis reagent and 10 ml sodium carbonate solution were added into each of the volumetric and were made up to 100 ml with water. The solutions were mixed well and the color was measured after 30 minutes at 760 nm against experimental blank adjusted to 0 absorbency.

II.) Preparation of sample

5 g of sample was boiled for 30 minutes with 400 ml of water, cooled, transferred to a 500 ml volumetric flask and diluted to mark. Then the sample was shake well and filtered. An aliquot of the filtrate containing not more than 0.1 mg of tannin acid was used. The experiment was proceeded as in standard, and mg tannin acid was obtained from the standard curve.

The tannin content was calculated as follows:

$$\text{Tannins as Tannic acid (mg)} = \frac{\text{mg of tannic acid} \times \text{dilution (500 ml)}}{\text{ml of sample taken for color development (5 ml)} \times \text{weight of sample taken (5 g)}}$$

3.6 Statistical Analysis

The data collected from all the analyses were analyzed using the analysis of variance (two – way ANOVA Version 16.0), significant differences ($P < 0.05$) were determined using Tukey Test. The Statistical programme used was SPSS.

CHAPTER 4

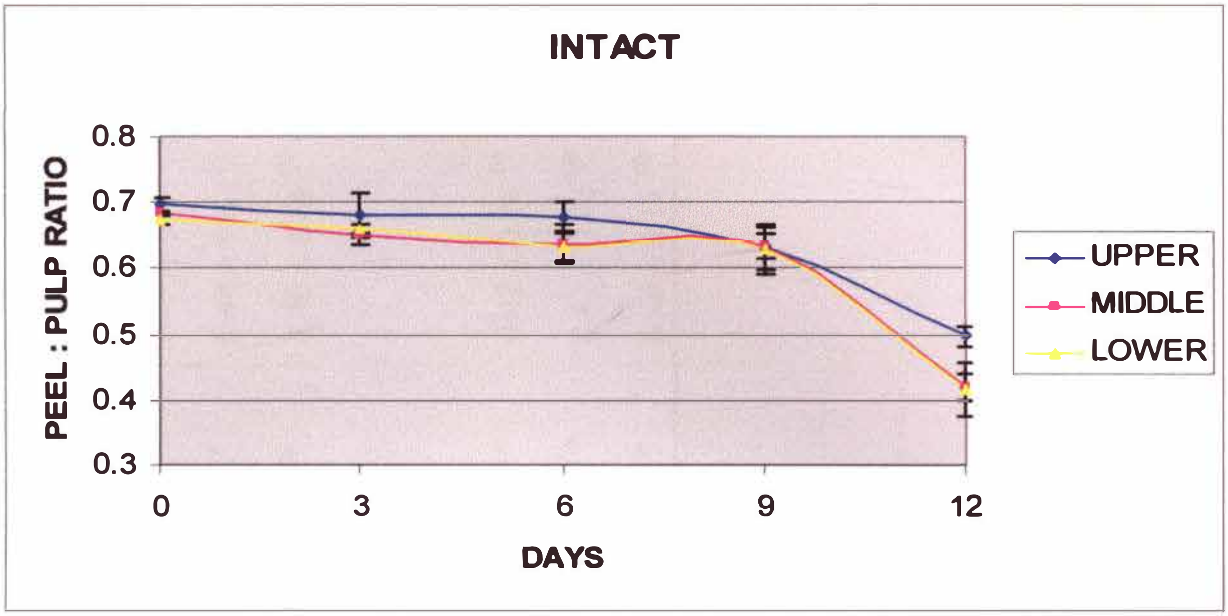
RESULTS AND DISCUSSIONS

4.1 Weight Ratio of Peel to Pulp

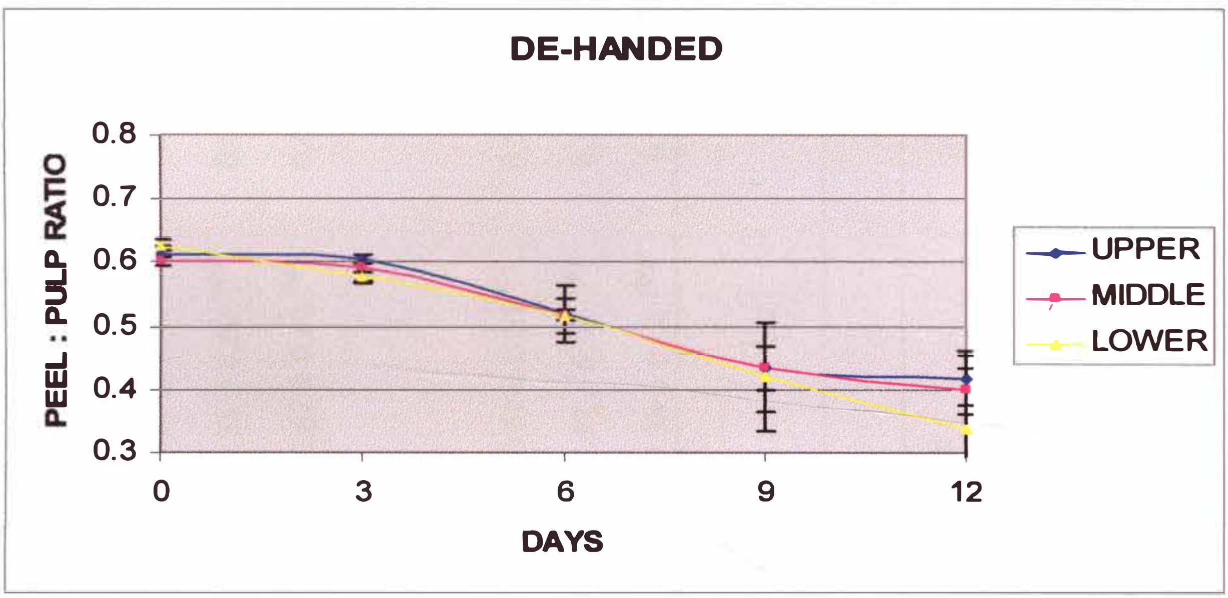
Figure 4.1 (A) and (B) showed the effects of peel to pulp weight ratio for intact and de-handed bunches which have gradual decreased in patterns over storage days. Both intact and de-handed bunches decreased in weight ratio of peel to pulp started by lower hands followed by middle hands and lastly upper hands. However the rates of deceasing were not the same. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches had shown continuous decreased in peel to pulp weight ratio which contributed by the lighter peel weight and heavier pulp weight, an indirect indication of ripening process.

There was no significant difference (P>0.05) observed in peel to pulp weight ratio between different positions within a bunch of intact and de-handed bunches of bananas (Table 4.1). According to Montenegro, (1988); Acedo and Bautista, (1989), the changes of water status have result in decreased in peel to pulp ratio during ripening process of bananas and which is proved and observed in this study.

According to Charles and Tung, (1973) and Lustre et al., (1976), there is a more rapid increased in sugars in the pulp during ripening compared with that in the peel. Thus, water loss from the peel is driven by transpiration and osmotic forces. Consequently, water content decreases in the peel but not in the pulp during ripening,



(A)



(B)

Figure 4.1: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on Weight Ratio of Peel to Pulp of 'Berangan' Banana during Storage.

Storage Conditions	Peel to Pulp Weight Ratio				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	0.69 ± 0.01^{Ab}	0.69 ± 0.01^{Ab}	0.66 ± 0.02^{Bb}	0.62 ± 0.02^{Bb}	0.48 ± 0.02^{Cb}
Middle	0.69 ± 0.01^{Ab}	0.65 ± 0.02^{ABb}	0.63 ± 0.03^{ABb}	0.60 ± 0.03^{Bb}	0.44 ± 0.02^{Cb}
Lower	0.68 ± 0.01^{Ab}	0.67 ± 0.01^{Ab}	0.64 ± 0.02^{ABb}	0.59 ± 0.04^{Bb}	0.46 ± 0.04^{Cb}
De-handed Bunch					
Upper	0.62 ± 0.01^{Ca}	0.61 ± 0.01^{Ca}	0.57 ± 0.05^{CDb}	0.51 ± 0.07^{CDb}	0.47 ± 0.04^{Db}
Middle	0.60 ± 0.01^{Ab}	0.57 ± 0.02^{ABb}	0.52 ± 0.01^{BCa}	0.47 ± 0.03^{CDb}	0.43 ± 0.03^{Db}
Lower	0.62 ± 0.01^{Dab}	0.58 ± 0.01^{Dba}	0.55 ± 0.03^{Db}	0.50 ± 0.09^{Db}	0.46 ± 0.11^{Db}

Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	NS

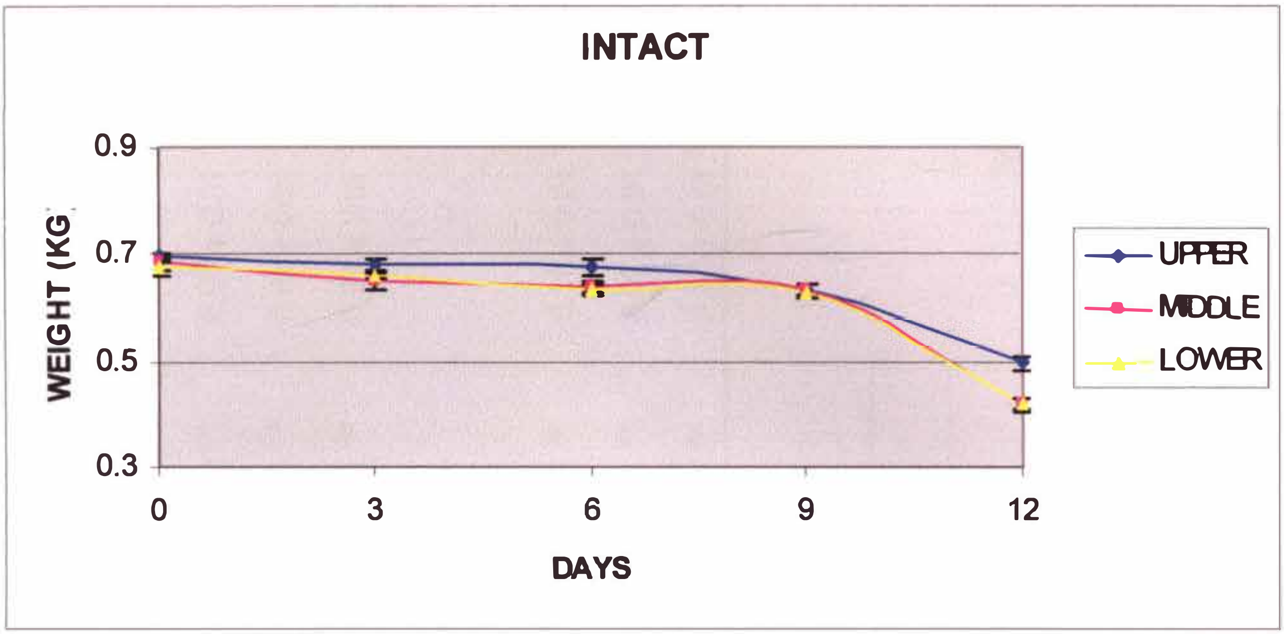
Note: Values in Table 4.1 are mean of 3 replicates means (n = 3) ± Standard Deviation
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P < 0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P < 0.05).
NS = Not Significant
* = Significant

resulting in the decreased of peel to pulp weight ratio (Suyanti and Dasuki, 1988).

4.2 Changes in Weight

Figure 4.2 (A) and (B) showed the changes in weight for intact and de-handed bunches which gave gradual decreased in patterns over storage days. As for intact bunches, more decreased in weight was started by lower hands followed by middle hands and lastly upper hands. In comparison the de-handed bunches, was also showed decreased of weight in lower hands followed by middle hands and lastly upper hands. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches have shown continuous decreased of weight loss which contributed to lighter finger of bananas which was an indication of ripening process. These patterns of decreasing in weight might correlated with those decreased in the patterns as observed in peel to pulp weight ratio (Figure 4.1).

It is clearly shown on the Figure 4.2 that, bananas from de-handed bunches have a steady decreased of weight loss compared to those intact bunches over storage days. There was a highly significant difference (P<0.05) observed in the weight between different positions within a bunch of intact and de-handed bunches of bananas (Table 4.2).



(A)

(B)

Figure 4.2: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on Changes in Weight of 'Berangan' Banana during Storage.

Storage Conditions	Changes in Weight				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	0.11 ± 0.01^{Aa}	0.10 ± 0.01^{Aa}	0.10 ± 0.01^{Aa}	0.10 ± 0.01^{Aa}	0.09 ± 0.01^{Aa}
Middle	0.11 ± 0.01^{Aa}	0.10 ± 0.01^{Aa}	0.10 ± 0.01^{Aa}	0.09 ± 0.01^{Aa}	0.09 ± 0.01^{Aa}
Lower	0.10 ± 0.01^{Aa}	0.09 ± 0.01^{Aa}	0.08 ± 0.01^{Aa}	0.08 ± 0.01^{Aa}	0.07 ± 0.01^{Aa}
De-handed Bunch					
Upper	0.13 ± 0.14^{Ba}	0.12 ± 0.01^{Ba}	0.11 ± 0.01^{Ba}	0.11 ± 0.01^{Ba}	0.10 ± 0.01^{Ba}
Middle	0.09 ± 0.02^{Bb}	0.08 ± 0.01^{Bb}	0.07 ± 0.01^{Bb}	0.07 ± 0.01^{Bb}	0.07 ± 0.01^{Bb}
Lower	0.12 ± 0.07^{Bab}	0.11 ± 0.01^{Ba}	0.11 ± 0.01^{Ba}	0.10 ± 0.01^{Ba}	0.10 ± 0.01^{Ba}

Test of Significant	
Upper Intact Vs. Upper De-handed	*
Middle Intact Vs. Middle De-handed	*
Lower Intact Vs. Lower De-handed	*

Note: Values in Table 4.2 are mean of 3 replicates means (n = 3) ± Standard Deviation
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P < 0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P < 0.05).
NS = Not Significant
* = Significant

The decreased in weight has shown that less water is loss through transpiration and osmotic forces from peel and pulp over storage day resulting in heavier weight of banana as also reported by Suyanti and Dasuki, 1988. Besides, the decrease of weight loss also related to the accumulation of sugar as empty pores in bananas pulp were filled up with sugar from the conversion of starch thus resulting in heavier weight of a finger of banana (Charles and Tung, (1973) and Lustre et al., (1976)).

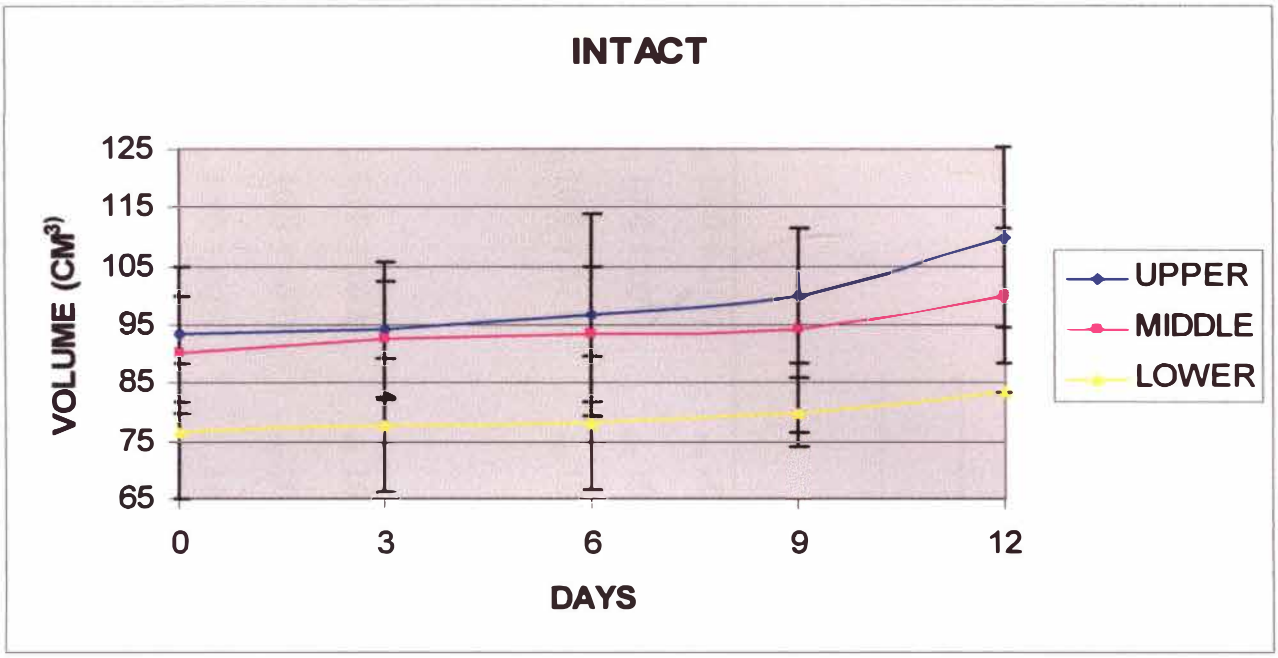
4.3 Fruit Volume

Figure 4.3 (A) and (B) showed the fruit volume for intact and de-handed bunches had gradual increased in patterns over storage days. As for intact bunches, an increase in fruit volume was observed in middle hands followed by upper hands and lastly lower hands. In comparison with de-handed bunches, an increase of fruit volume was started by upper hands followed by lower hands and lastly middle hands. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches have shown continuous and sharp increase of fruit volume which contributed to heavier finger of bananas and it was an indication of ripening process.

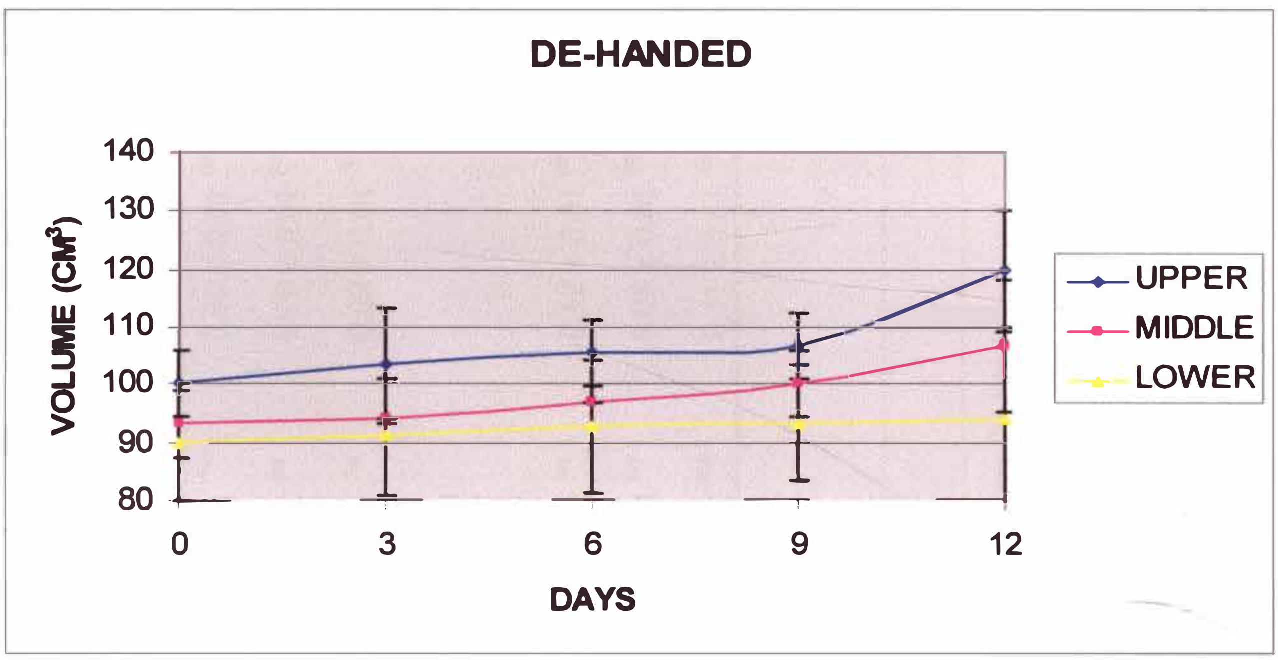
These patterns of fruit volume increased were correlated with those decreased patterns as observed in Figures 4.1 (A and B) for peel to pulp weight ratio and Figures

4.2 (A and B) for changes in weight respectively. There were significant differences ($P<0.05$) observed in volume between upper hands and lower hands within a bunch of both intact and de-handed bunches of bananas, however there was also no significant difference ($P>0.05$) observed between middle hands of both intact and de-handed bunches of bananas (Table 4.3).

As fruits ripen fruit volume increase due to rapid movement of water molecules towards pulp from peel over storage days thus resulting in heavier weight and greater volume of banana. At the same time, less moisture loss has occurred (Madamba et al., 1977). Therefore, the same factors and mechanisms occurred as in peel to pulp weight ratio and changes in weight analyses that resulting in an increase of fruit volume over storage days. Besides, according to Montenegro, 1988, conversion of starch to sugar also contributes to an increase in fruit volume.



(A)



(B)

Figure 4.3: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on Fruit Volume of 'Berangan' Banana during Storage

Storage Conditions	Fruit Volume				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	0.11 ± 0.01^{Aa}	0.10 ± 0.01^{Aa}	0.10 ± 0.01^{Aa}	0.10 ± 0.01^{Aa}	0.09 ± 0.01^{Aa}
Middle	0.11 ± 0.01^{Aa}	0.10 ± 0.01^{Aa}	0.10 ± 0.01^{Aa}	0.09 ± 0.01^{Aa}	0.09 ± 0.01^{Aa}
Lower	0.10 ± 0.01^{Aa}	0.09 ± 0.01^{Aa}	0.08 ± 0.01^{Aa}	0.08 ± 0.01^{Aa}	0.07 ± 0.01^{Aa}
De-handed Bunch					
Upper	0.13 ± 0.14^{Ba}	0.12 ± 0.01^{Ba}	0.11 ± 0.01^{Ba}	0.11 ± 0.01^{Ba}	0.10 ± 0.01^{Ba}
Middle	0.09 ± 0.02^{Bb}	0.08 ± 0.01^{Bb}	0.07 ± 0.01^{Bb}	0.07 ± 0.01^{Bb}	0.07 ± 0.01^{Bb}
Lower	0.12 ± 0.07^{Bab}	0.11 ± 0.01^{Ba}	0.11 ± 0.01^{Ba}	0.10 ± 0.01^{Ba}	0.10 ± 0.01^{Ba}

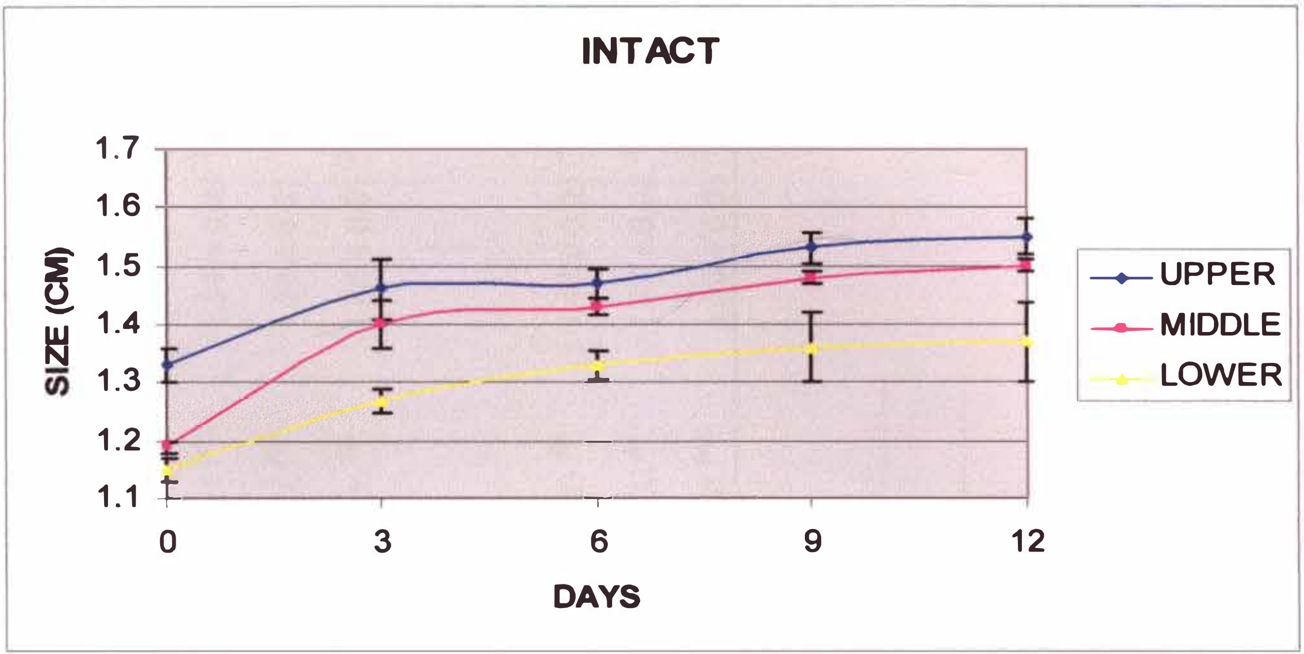
Test of Significant	
Upper Intact Vs. Upper De-handed	*
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	*

Note: Values in Table 4.3 are mean of 3 replicates means (n=3) ± Standard Deviation
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

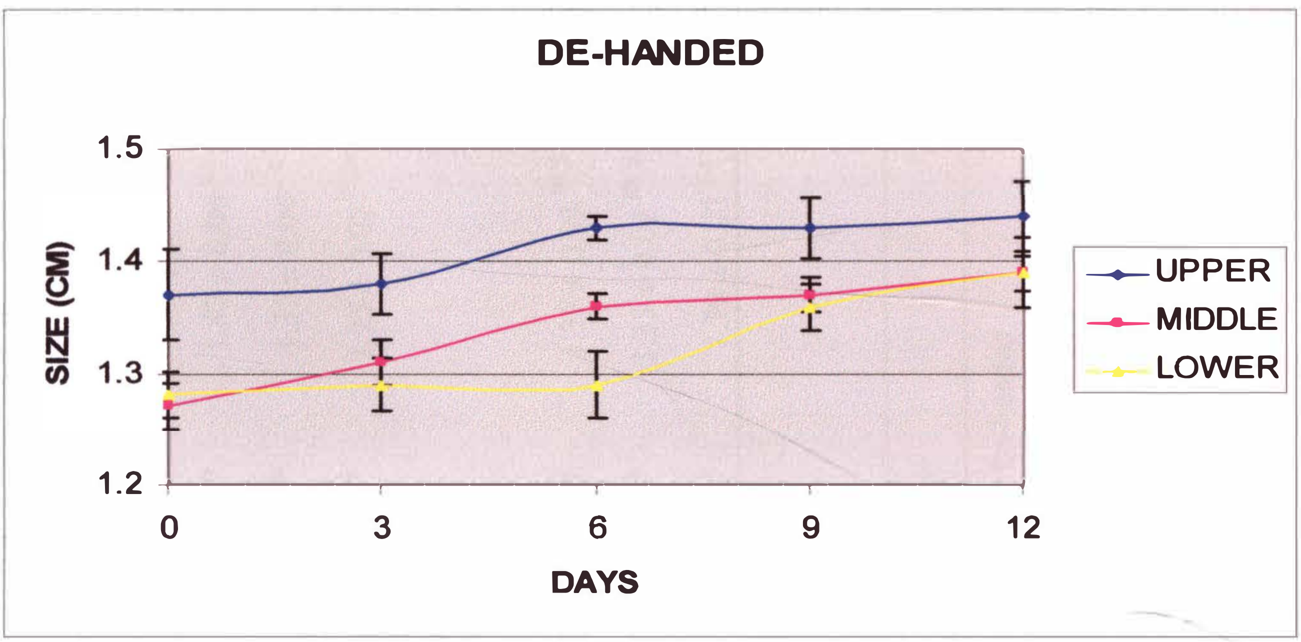
4.4 Fruit Size

Figure 4.4 (A) and (B) showed the fruit size in terms of length to girth ratio for intact and de-handed bunches which had gradual increased in patterns over storage days. Both intact and de-handed bunches of bananas have shown increased in fruit size (length to girth ratio) which first observed in upper hands followed by middle hands and lastly lower hands. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches have shown continuous gradual increased of fruit size (length to girth ratio) which contributed to larger in size of bananas fingers and it was an indication of fruits ripening process is taking place.

These patterns of fruit size length to girth ratio increased were into-related with those increased patterns as observed in fruit volume (Figure 4.3). It is clearly shown on Figure 4.4 that, bananas form intact bunches have a steady increased of fruit size (length to girth ratio) compared to those de-handed bunches (Figure 4.4 B) over storage days. There was no significant difference (P>0.05) observed in fruit size (length to girth ratio) between different positions within a bunch of intact and de-handed bunches of bananas (Table 4.4).



(A)



(B)

Figure 4.4: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on Fruit Size (Length to Girth Ratio) of 'Berangan' Banana during Storage.

Storage Conditions	Fruit Size				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	1.30 ± 0.03^{Da}	1.42 ± 0.06^{Ca}	1.46 ± 0.03^{BCa}	1.51 ± 0.03^{BCb}	1.54 ± 0.03^{Bb}
Middle	1.19 ± 0.01^{Db}	1.35 ± 0.04^{Ca}	1.43 ± 0.02^{Ba}	1.48 ± 0.01^{ABb}	1.50 ± 0.01^{Ab}
Lower	1.17 ± 0.02^{Db}	1.25 ± 0.02^{CDb}	1.33 ± 0.03^{BCb}	1.43 ± 0.06^{Bb}	1.45 ± 0.07^{Bb}
De-handed Bunch					
Upper	1.33 ± 0.04^{Cc}	1.37 ± 0.03^{BCb}	1.43 ± 0.01^{Bb}	1.46 ± 0.03^{Ab}	1.47 ± 0.03^{Ab}
Middle	1.29 ± 0.02^{Cc}	1.33 ± 0.02^{BCbc}	1.37 ± 0.01^{ABb}	1.39 ± 0.02^{Ac}	1.41 ± 0.02^{Ac}
Lower	1.29 ± 0.02^{Cc}	1.30 ± 0.23^{Cc}	1.32 ± 0.03^{BCc}	1.35 ± 0.02^{BCc}	1.38 ± 0.03^{Bc}

Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	NS

Note: Values in Table 4.4 are mean of 3 replicates means (n=3) ± Standard Deviation
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

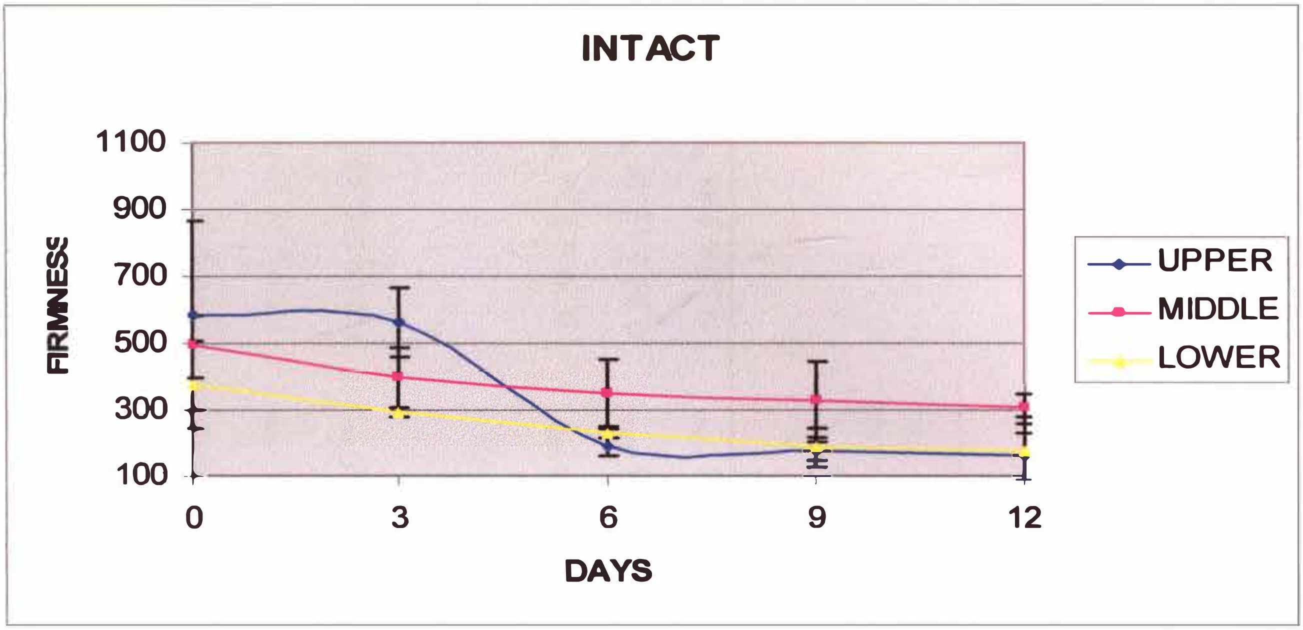
According to Charles and Tung, (1973), as fruit ripens, the length as well as diameter and girth of fruits will directly increase and directly proportional to each others over storage days. Therefore as length and girth increase, so does the peel to pulp weight ratio (Simmonds, 1962). According to Madamba et al., (1977), an increased in fruit size is primarily due to the increased in accumulation of sugar as fruit ripens and the expand or the development of cell wall. However the mechanism and enzymes involved in influencing fruit size were still not well understood.

4.5 Peel Texture

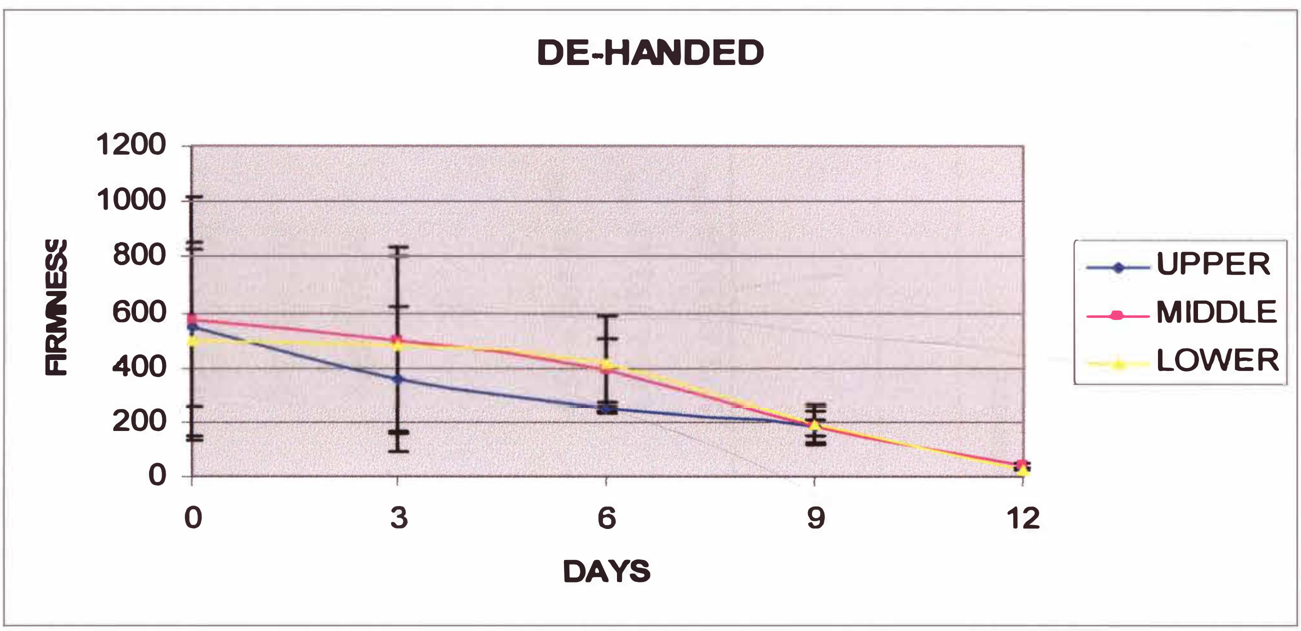
Figure 4.5 (A) and (B) had shown the effects of peel texture for bananas in intact and de-handed bunches which had gradual decreased in patterns over storage days. As for intact bunches, decreased in peel texture was first observed in the lower hands followed by middle hands and lastly upper hands. In comparison with de-handed bunches, the decreased of peel texture was started by upper hands followed by middle hands and lastly lower hands. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches have shown continuous and steady decreased of peel texture which contributed to firmer or softer peel texture of bananas fingers and which is an indirect indication of fruits ripening.

These patterns of peel texture decreased were into-related with those decreased patterns as observed in peel to pulp weight ratio (Figure 4.1) and changes in weight (Figure 4.2). This is due to more water is loss trough transpiration and osmotic forces from peel over storage days resulting the peel less firmness and turgid (Tucker at el., 1990). Other than that, according to Simmonds, (1962), the decrease in peel texture also due to the presence of cellulose and hemicelluloses in the peel which at maturity were converted to starch .These patterns of decreases also correspond with decrease in pulp texture.

It is clearly shown on the Figure 4.5 that, bananas form de-handed bunches have a steady decreased of peel texture compared to those intact bunches over storage days. There was no significant difference (P>0.05) observed in peel texture between different positions within a bunch of intact and de-handed bunches of bananas (Table 4.5). In addition, textural properties of ripen bananas is correlated well with their peel color and suggested as a simple physical texture measurement during bulk storage (Ramaswamy and Tung, 1989). Besides, fruits soften gradually as ripening process is primarily influenced by physical and chemical attributes such as starch and sugar content, peel thickness and its volume (Lizada and Novenario, (1983); Montenegro, (1988); Biglete and Bautista, (1987).



(A)



(B)

Figure 4.5: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on Peel Fruit Texture of 'Berangan' Banana during Storage.

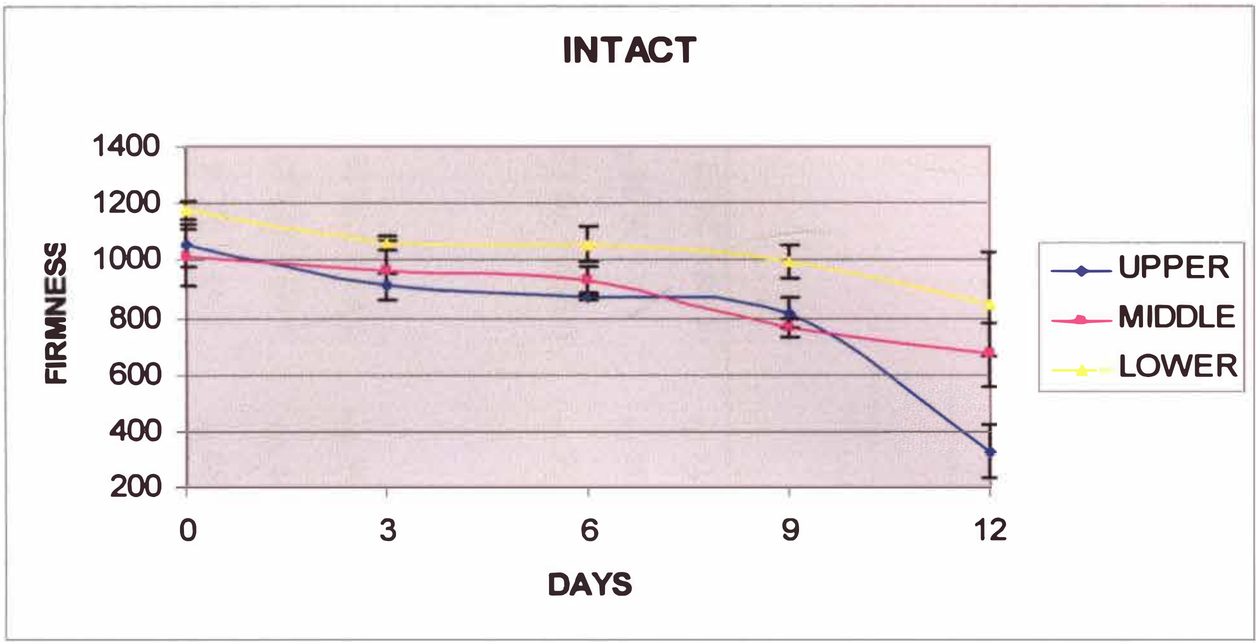
Storage Conditions	Peel Texture				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	4.75 ± 285.30^{Aa}	2.84 ± 104.91^{Aa}	1.92 ± 25.68^{Aa}	1.21 ± 28.75^{Aa}	0.13 ± 70.52^{Aa}
Middle	4.78 ± 91.71^{Aa}	3.92 ± 90.42^{Aa}	3.35 ± 99.81^{ABa}	2.42 ± 112.71^{ABa}	1.43 ± 45.12^{Ba}
Lower	3.91 ± 131.36^{Aa}	2.58 ± 15.04^{Aa}	2.41 ± 13.40^{Aa}	2.07 ± 57.29^{Aa}	1.87 ± 103.46^{Aa}
De-handed Bunch					
Upper	5.42 ± 287.54^{Aa}	4.56 ± 264.55^{ABa}	1.95 ± 110.81^{ABa}	1.51 ± 27.27^{ABa}	0.29 ± 3.26^{Ba}
Middle	7.94 ± 444.18^{Aa}	4.60 ± 332.82^{ABa}	2.34 ± 118.43^{ABa}	1.22 ± 57.46^{ABa}	0.39 ± 12.48^{Ba}
Lower	6.96 ± 354.42^{Aa}	5.33 ± 321.09^{ABa}	2.60 ± 177.34^{ABa}	1.23 ± 71.06^{ABa}	0.30 ± 5.86^{Ba}

Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	NS

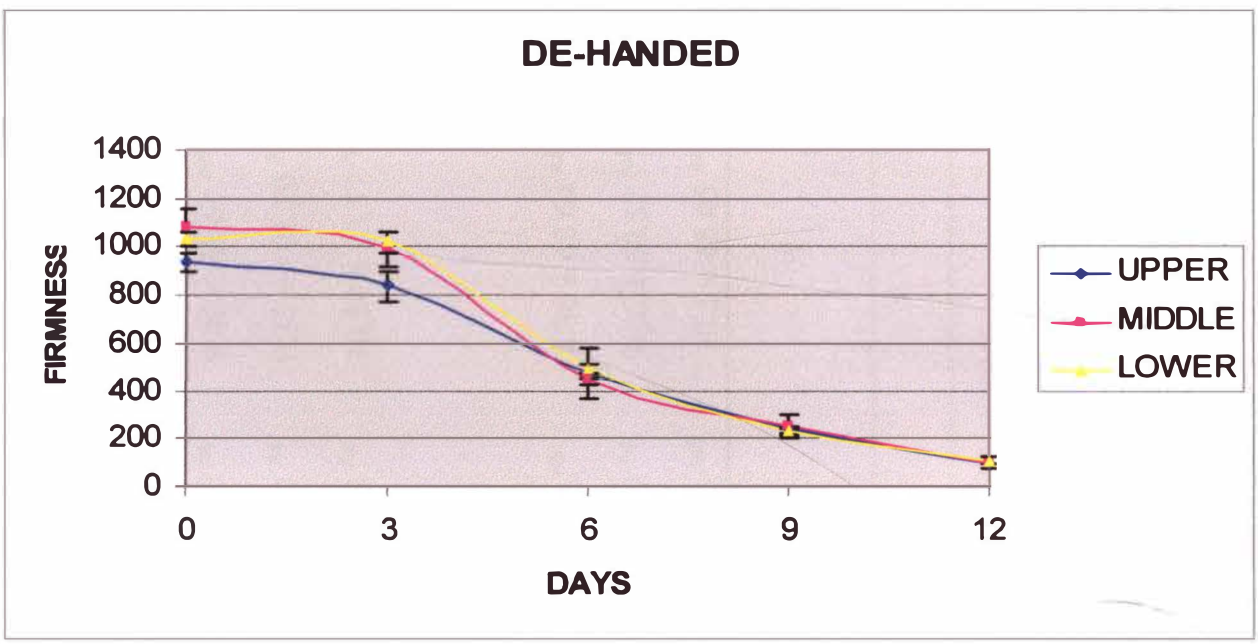
Note: Values in Table 4.5 are mean of 3 replicates means (n=3) ± Standard Deviation
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

4.6 Pulp Texture

Figure 4.6 (A) and (B) showed the effects of pulp texture for intact and de-handed bunches which have decreased in patterns over storage days. As for intact bunches, a sharp decreased was first observed in upper hands followed by gradual decreased observed in lower hands and lastly middle hands. In comparison with de-handed bunches, a sharp decreased was observed even after day 3 in all the positions and the firmness were almost similar among three positions after day 6. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches have shown continuous decreased of pulp texture which contributed to firmer or softer pulp fruit texture of bananas fingers and which was an indirect indication of fruit ripening process. These patterns of pulp texture decreased were into-related with those decreased patterns as observed in peel to pulp weight ratio (Figure 4.1), changes in weight (Figure 4.2) and peel texture (Figure 4.5). It is clearly shown on Figure 4.6 that, bananas form de-handed bunches have a steady decreased of pulp texture compared to those intact bunches over storage days and towards the end of storage day the pulp texture in de-handed bunches of bananas achieved the same values and it was also reported by Madamba et al., (1977). There was no significant difference (P>0.05) observed in pulp fruit texture,



(A)



(B)

Figure 4.6: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on Pulp Fruit Texture of 'Berangan' Banana during Storage.

Storage Conditions	Pulp Texture				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	10.17 ± 74.90^{Aa}	9.49 ± 65.64^{ABa}	9.05 ± 8.97^{ABa}	8.15 ± 51.98^{Ba}	2.41 ± 92.25^{Ca}
Middle	10.10 ± 98.63^{Aa}	9.33 ± 101.20^{Aa}	9.26 ± 49.29^{Aa}	8.0 ± 31.57^{ABa}	5.93 ± 111.82^{Ba}
Lower	11.20 ± 32.84^{Aa}	10.50 ± 23.57^{Aa}	9.39 ± 63.07^{ABa}	8.76 ± 58.96^{ABa}	7.43 ± 179.76^{Bb}
De-handed Bunch					
Upper	9.36 ± 34.49^{Ab}	8.36 ± 65.64^{Ab}	5.40 ± 106.59^{Ba}	2.57 ± 10.56^{Ca}	0.959 ± 70.52^{Da}
Middle	10.80 ± 73.59^{Aa}	9.46 ± 69.52^{Aab}	4.18 ± 14.59^{Ba}	2.36 ± 48.39^{Ca}	1.0 ± 26.38^{Ca}
Lower	10.03 ± 26.42^{Aab}	10.1 ± 45.05^{Aa}	5.27 ± 20.78^{Ba}	2.17 ± 13.35^{Ca}	1.08 ± 24.52^{Da}

Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	*

Note: Values in Table 4.6 are mean of 3 replicates means (n=3) ± Standard Deviation
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

between upper hands and middle hands within a bunch of both intact and de-handed bunches of bananas, however there was also a highly significant difference (P>0.05) observed between lower hands of both intact and de-handed bunches of bananas (Table 4.6).

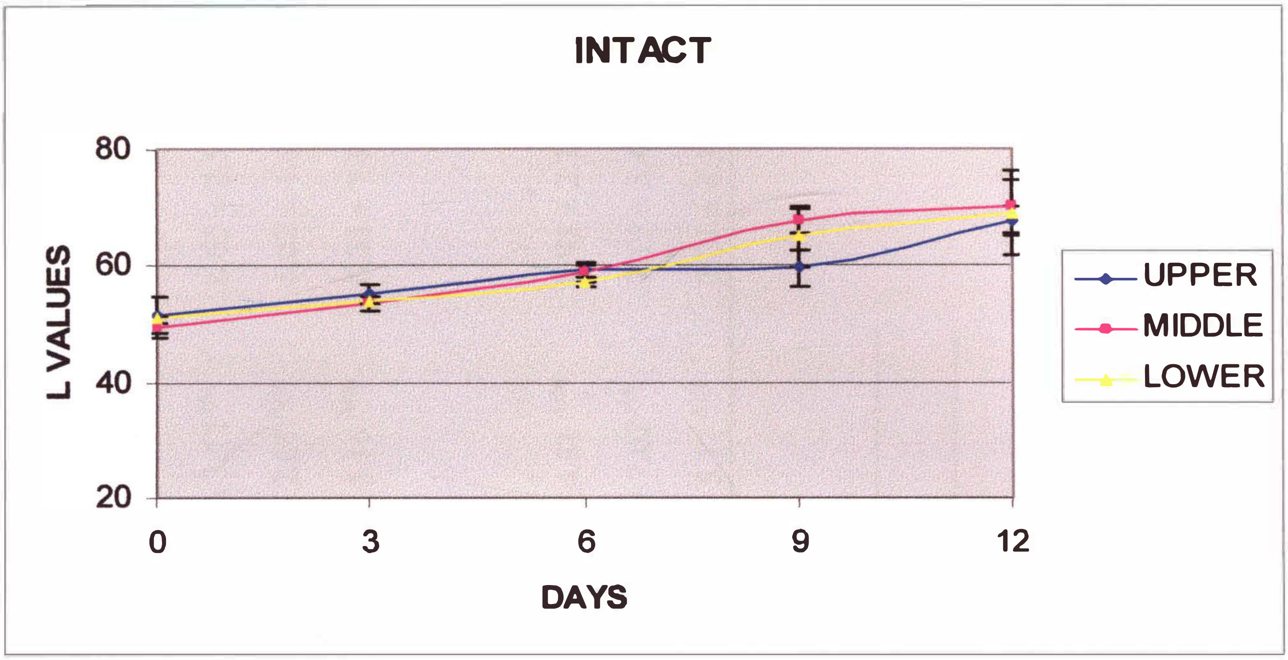
According to Madamba et al., (1977), softening of banana fruits is primarily due to the breakdown of starch and other non-pectic polysaccharide in the pulp where starch imparts cellular rigidity is converted to sugars during ripening process. Besides, this is also due to the solubilization of pectic substances in the cell wall and middle lamella. Increased levels of water soluble-pectin's are observed with advancing ripening in 'Saba' banana by Rivera, (1969). This indicates that polygalacturonase (PG) and pectin methyl estherase (PME) were involved in pectin breakdown processes which contributed to softer pulp fruit texture. However the existence of these processes in banana has not been established (Tucker at el., 1990). Therefore, firmness of banana is closely related to reducing sugar and starch content during ripening at 60 ˚C (15.6 ˚C) (Finney et al., 1967). By contrast, bananas ripened at 16 ˚C and 25 ˚C result in firmer texture compared to those bananas ripened at 18 ˚C and 19 ˚C.

4.7 Peel Color

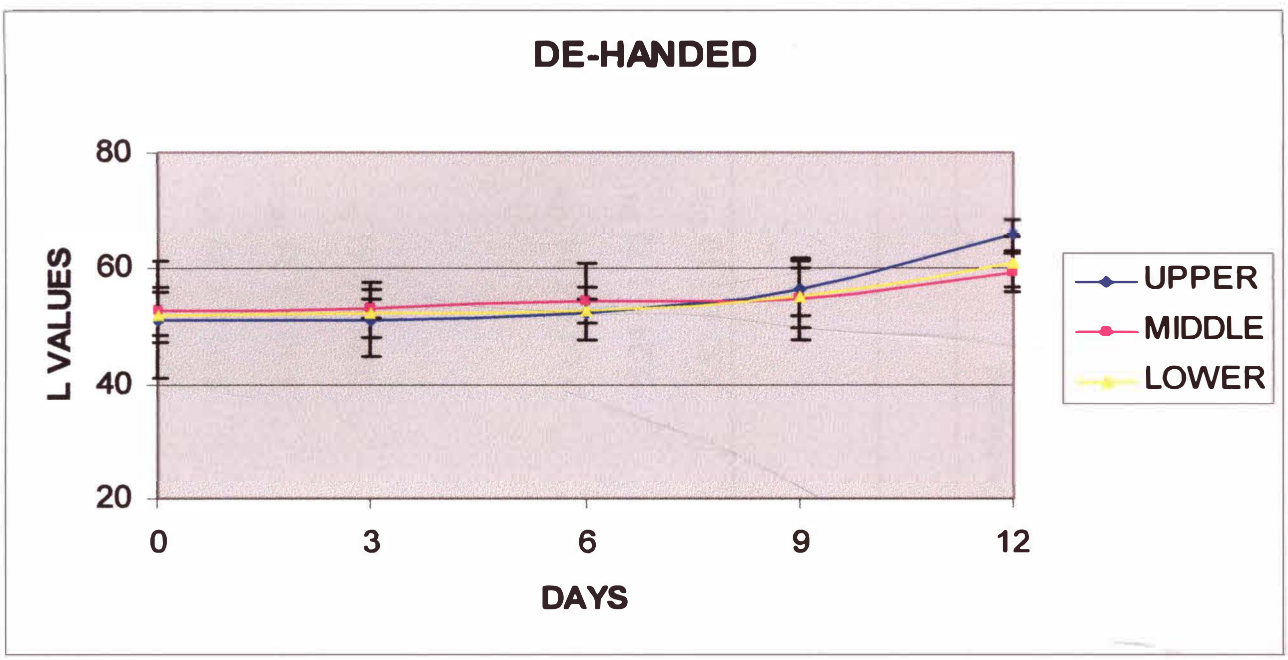
Figure 4.7.1 (A) and (B) showed the effects of peel color (Hunter 'L' value) for intact and de-handed bunches which have gradual increased in patterns over storage days. As for intact bunches, an increased in peel color (Hunter 'L' value) was observed first by upper hands followed by middle hands and lastly upper hands. In comparison with de-handed bunches, an increased of peel color (Hunter 'L' value) was first observed by middle hands followed by lower hands and lastly upper hands. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches had shown continuous increased of peel color (Hunter 'L' value) which contributed to lighter color of peel glossiness and it was indirect indication of fruit ripening process.

It is clearly seen on the Figure 4.7.1 that, both intact and de-handed bunches of bananas have shown steady increased of peel color (Hunter 'L' value) over storage days. There was no significant difference ($P>0.05$) observed in fruit peel color (Hunter 'L' value) between different positions within a bunch of intact and de-handed bunches of bananas (Table 4.7.1). Banana peel yellowing is due primarily to chlorophyll breakdown (Montenegro, 1988).

Besides, according to Lizada et al., (1983), the chlorophyll content decrease slowly with ripening and generally a certain amount of the green pigment remains in the fruit especially in the internal tissues. Therefore, the degradation of chlorophyll as been ascribed to chlorophyllase action. Thus the loss of chlorophyll pigments reveals the carotenoid pigments where there is no net carotenoids synthesis during ripening process. The peel carotenoids consist mainly of α- carotene, β- carotene and lutein occurring at



(A)



(B)

Figure 4.7.1: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on 'L' Value Peel Color of 'Berangan' Banana during Storage.

Storage Conditions	Peel Color (Hunter 'L' value)				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	4.67 ± 3.55^{Da}	5.01 ± 1.49^{CDa}	5.54 ± 1.31^{BCa}	5.91 ± 3.12^{Ba}	6.65 ± 2.59^{Aa}
Middle	5.07 ± 0.83^{Ca}	5.30 ± 1.31^{BCa}	5.55 ± 1.73^{ABCa}	5.76 ± 2.07^{ABa}	6.08 ± 4.45^{Aa}
Lower	5.14 ± 0.62^{Ba}	5.25 ± 0.61^{Ba}	5.47 ± 0.75^{ABa}	5.49 ± 5.16^{ABa}	6.34 ± 7.18^{Aa}
De-handed Bunch					
Upper	5.26 ± 10.17^{Ba}	5.64 ± 6.28^{ABa}	6.25 ± 4.54^{ABa}	6.65 ± 4.81^{ABa}	6.93 ± 2.75^{Aa}
Middle	5.04 ± 4.07^{Ba}	5.24 ± 1.72^{Ba}	5.88 ± 6.74^{ABa}	6.72 ± 7.02^{Aa}	7.13 ± 3.46^{Aa}
Lower	4.86 ± 4.31^{Ca}	5.52 ± 4.10^{BCa}	5.85 ± 1.92^{BCa}	6.47 ± 5.17^{ABa}	7.01 ± 4.39^{Aa}

Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	NS

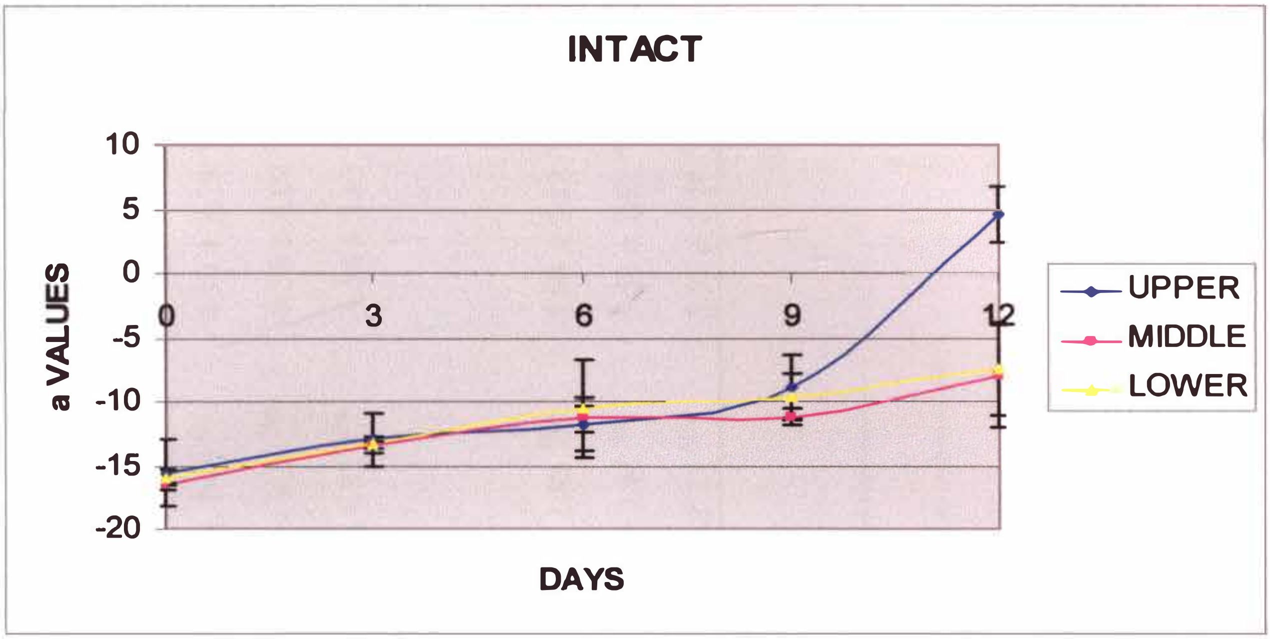
Note: Values in Table 4.7.1 are mean of 3 replicates means (n=3) ± Standard Deviation (3 readings/ replicate)
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

concentrations ranging from 5 to 10 ug/ g fresh weight (Gross et al., 1976; Montenegro, 1988). All these mechanisms have contributed to an increase in lightness of fruit peel color (Hunter 'L' value).

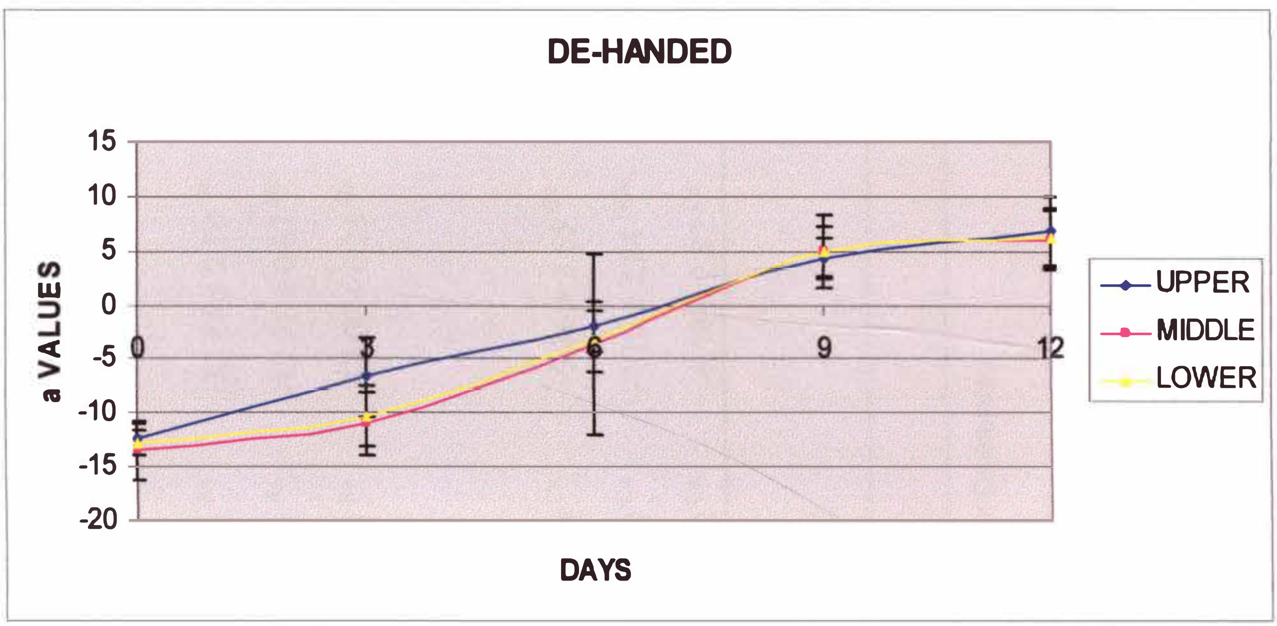
Figure 4.7.2 (A) and (B) showed the effects of peel color (Hunter 'a' value) for intact and de-handed bunches which have gradual increased in patterns over storage days. Both intact and de-handed bunches of bananas had shown increased in peel color (Hunter 'a' value) started from upper hands followed by middle hands and lastly lower hands. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches have shown continuous increased in fruit peel color (Hunter 'a' value) which contributed to higher red and green color density and it was an indirect indication of fruits ripening process.

These patterns of peel color (Hunter 'a' value) increased were into-related with those increased patterns as observed in peel color (Hunter 'L' value) (Figure 4.7.1). It is clearly shown on the Figure 4.7.2 that, both bananas form intact and de-handed bunches have a steady increased of peel color (Hunter 'a' value) over storage days.

There was no significant difference (P>0.05) observed in peel color (Hunter 'a' value) between upper hands of intact and de-handed bunches, however, there was a highly significant difference (P<0.05) observed between middle and lower hands of both



(A)



(B)

Figure 4.7.2: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on 'a' Value Peel Color of 'Berangan' Banana during Storage.

Storage Conditions	Peel Color (Hunter 'a' value)				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	-13.95 ± 2.61^{Ba}	-12.43 ± 2.10^{Ba}	-10.52 ± 2.08^{Ba}	-8.01 ± 2.46^{Ba}	4.93 ± 2.19^{Aa}
Middle	-13.20 ± 0.24^{Aa}	-12.91 ± 0.67^{Aa}	-12.47 ± 0.97^{Aa}	-11.21 ± 0.58^{Aa}	-9.38 ± 4.01^{Aa}
Lower	-13.34 ± 0.63^{Ba}	-13.00 ± 0.25^{Ba}	-12.71 ± 3.75^{Ba}	-7.91 ± 1.82^{ABa}	-4.54 ± 3.63^{Aa}
De-handed Bunch					
Upper	-11.84 ± 1.46^{Ca}	-9.86 ± 3.65^{Ca}	-1.39 ± 2.32^{Ba}	4.18 ± 1.88^{ABa}	5.94 ± 3.13^{Aa}
Middle	-14.93 ± 2.68^{Ca}	-1.10 ± 2.84^{BCa}	-1.06 ± 8.35^{ABa}	5.13 ± 3.41^{Aa}	5.51 ± 2.67^{Aa}
Lower	-12.35 ± 1.22^{Ca}	-9.18 ± 2.82^{Ca}	-1.41 ± 2.78^{Ba}	4.79 ± 2.25^{ABa}	5.55 ± 2.78^{Aa}

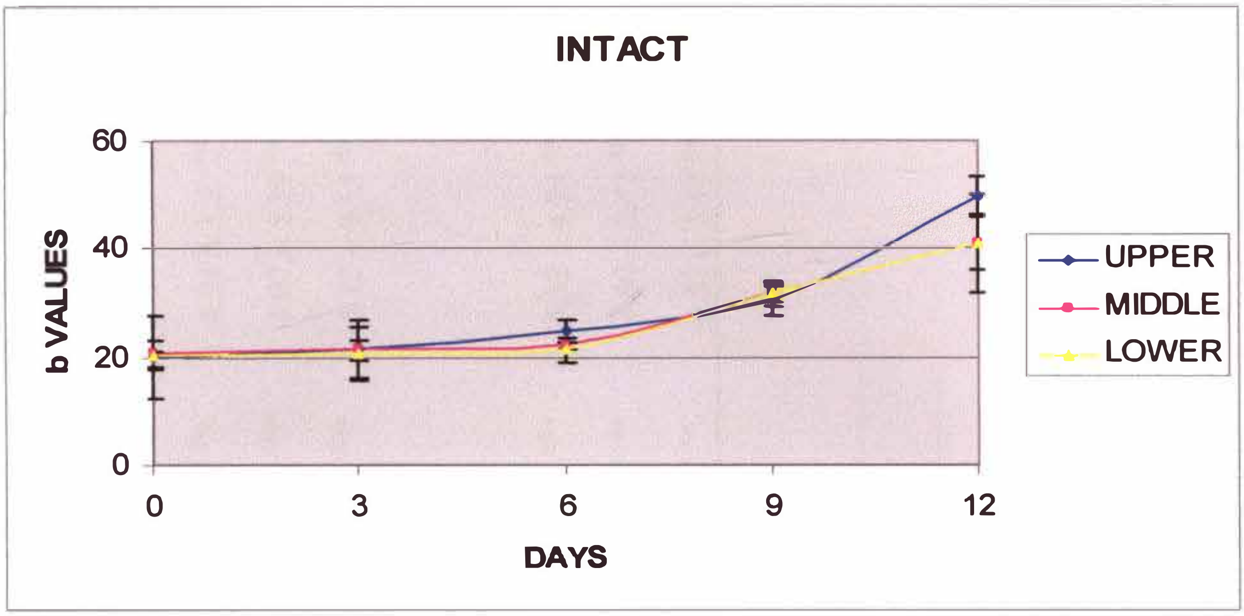
Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	*
Lower Intact Vs. Lower De-handed	*

Note: Values in Table 4.7.2 are mean of 3 replicates means (n=3) ± Standard Deviation (3 readings/ replicate)
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

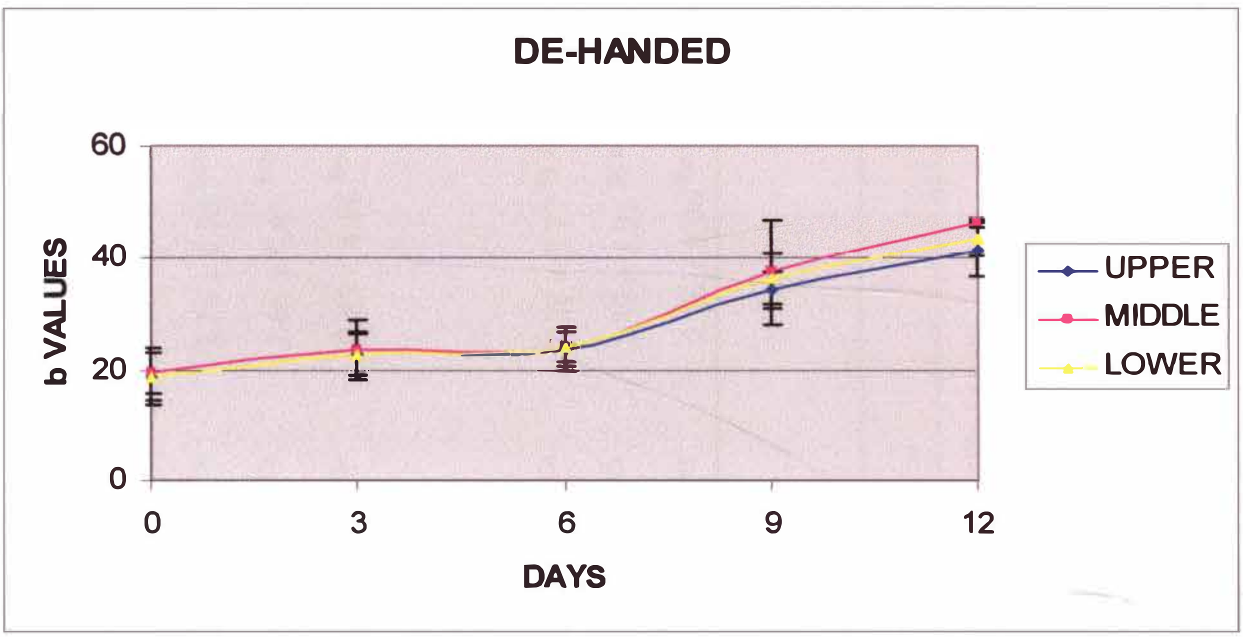
intact and de-handed bunches of bananas (Table 4.7.2). According to Montenegro, (1988); Artes and Lizada, (1988) and Munasque, (1987), the patterns of an increase in the Hunter 'a' value color for peel is correspond and directly proportional with an increase in Hunter 'L' and 'b' values color. In other words, an increase in the value of Hunter 'L' also resulting in an increase in Hunter 'a' and 'b' values.

Figure 4.7.3 (A) and (B) showed the effects of peel color (Hunter 'b' value) for intact and de-handed bunches which have gradual increased in patterns over storage days. As for intact bunches, an increased in peel color (Hunter 'b' value) was first observed in upper hands followed by middle hands and lastly upper hands. In comparison with de-handed bunches, an increased of peel color (Hunter 'b' value) was started by middle hands followed by lower hands and lastly upper hands. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches have shown continuous increased of peel color (Hunter 'b' value) which contributed to an increased color density of yellow and blue color which is an indirect indication of fruit ripening process.

It is clearly seen on the Figure 4.7.3 that, both intact and de-handed bunches of bananas have shown steady increased of peel color (Hunter 'b' value) over storage days. There was no significant difference (P>0.05) observed in fruit peel color (Hunter 'b' value) between different positions within a bunch of intact and de-handed bunches of



(A)



(B)

Figure 4.7.3: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on 'b' Value Peel Color of 'Berangan' Banana during Storage.

Storage Conditions	Peel Color (Hunter 'b' value)				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	1.71 ± 1.36^{Da}	2.16 ± 1.75^{CDa}	2.69 ± 2.13^{BCa}	3.25 ± 2.68^{Ba}	4.94 ± 3.57^{Aa}
Middle	2.12 ± 2.54^{Ca}	2.66 ± 5.45^{BCa}	3.05 ± 0.52^{BCa}	3.47 ± 1.68^{ABa}	4.07 ± 5.19^{Aa}
Lower	1.91 ± 7.83^{Ba}	2.43 ± 4.86^{Ba}	3.07 ± 2.38^{ABa}	3.30 ± 2.30^{ABa}	4.12 ± 9.13^{Aa}
De-handed Bunch					
Upper	1.83 ± 5.18^{Ca}	2.28 ± 3.77^{BCa}	2.68 ± 3.51^{BCa}	3.38 ± 3.26^{ABa}	4.32 ± 4.74^{Aa}
Middle	2.01 ± 3.72^{Ca}	2.39 ± 5.25^{BCa}	2.69 ± 2.71^{BCa}	3.65 ± 9.29^{ABa}	4.80 ± 0.72^{Aa}
Lower	1.73 ± 4.31^{Ba}	2.26 ± 3.96^{Ba}	2.53 ± 3.43^{Ba}	3.81 ± 4.57^{Aa}	4.63 ± 3.17^{Aa}

Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	NS

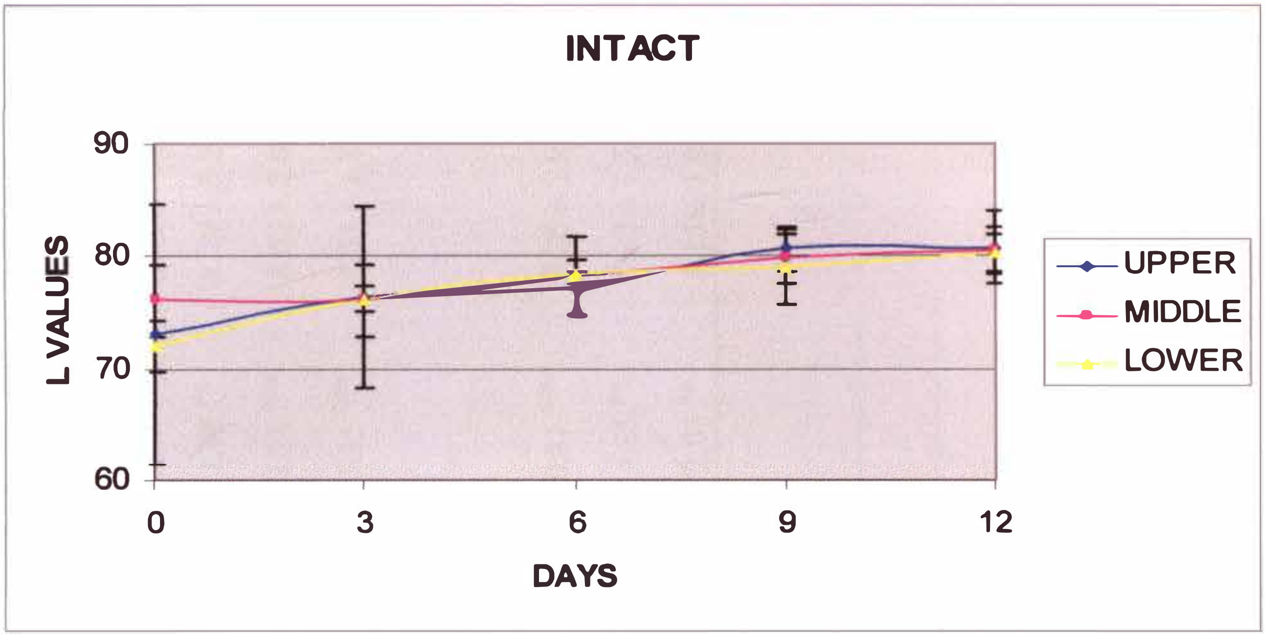
Note: Values in Table 4.7.3 are mean of 3 replicates means (n=3) ± Standard Deviation (3 readings/ replicate)
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

bananas (Table 4.7.3). According to Gross et al., (1976); Montenegro, (1988), Hunter 'b' value represents yellow and blue colors which are closely related to an increase and decrease patterns of Hunter 'L' and 'a' values. Therefore as ripening process takes place, all Hunter values of 'L', 'a' and 'b' shown synchronization increase of color density which respect to lightness, red, green, yellow and lastly blue (Abd. Shukor et al., 1986).

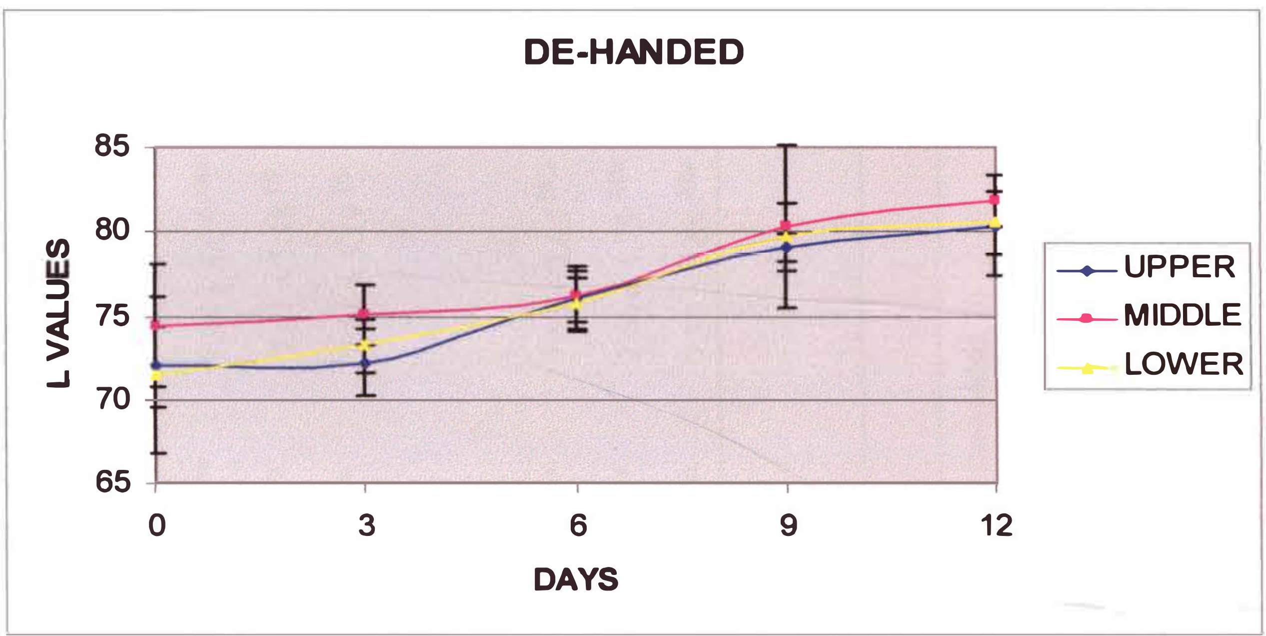
4.8 Pulp Color

Figure 4.8.1 (A) and (B) showed the effects of pulp color (Hunter 'L' value) for intact and de-handed bunches which have gradual increased in patterns over storage days. As for intact bunches, an increased in pulp color (Hunter 'L' value) was first observed by upper hands followed by lower hands and lastly middle hands. In comparison with de-handed bunches, an increased of pulp color (Hunter 'L' value) was started by lower hands followed by middle hands and lastly upper hands.

Towards the end of storage days, all three positions of hands in both intact and de-handed bunches have shown continuous increased of pulp color (Hunter 'L' value) which contributed to lighter color of peel glossiness of bananas fingers and it was an indirect indication of fruits ripening. These patterns of pulp color (Hunter 'L' value) increased



(A)



(B)

Figure 4.8.1: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on 'L' Value Pulp Color of 'Berangan' Banana during Storage.

Banana.

Storage Conditions	Pulp Color (Hunter 'L' value)				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	6.26 ± 11.56^{Ba}	7.38 ± 8.03^{ABa}	7.96 ± 2.48^{ABb}	8.13 ± 1.98^{Aa}	8.29 ± 3.27^{Aa}
Middle	5.69 ± 3.22^{Da}	7.61 ± 1.18^{Ca}	7.89 ± 0.42^{ACa}	8.17 ± 2.23^{ABa}	8.62 ± 2.05^{Aa}
Lower	5.51 ± 2.29^{Ca}	7.31 ± 3.19^{Ba}	7.33 ± 3.39^{Ba}	7.67 ± 3.35^{ABa}	8.33 ± 1.74^{Aa}
De-handed Bunch					
Upper	7.23 ± 2.39^{Ca}	7.53 ± 2.03^{BCa}	7.76 ± 1.83^{ABCa}	7.94 ± 0.81^{ABa}	8.26 ± 2.94^{Aa}
Middle	7.21 ± 3.63^{Ba}	7.66 ± 1.79^{ABa}	8.01 ± 1.57^{ABa}	8.29 ± 4.85^{Aa}	8.37 ± 1.52^{Aa}
Lower	7.21 ± 4.72^{Ba}	7.57 ± 1.65^{ABa}	7.75 ± 1.58^{ABa}	8.09 ± 2.01^{Aa}	8.15 ± 1.85^{Aa}

Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	NS

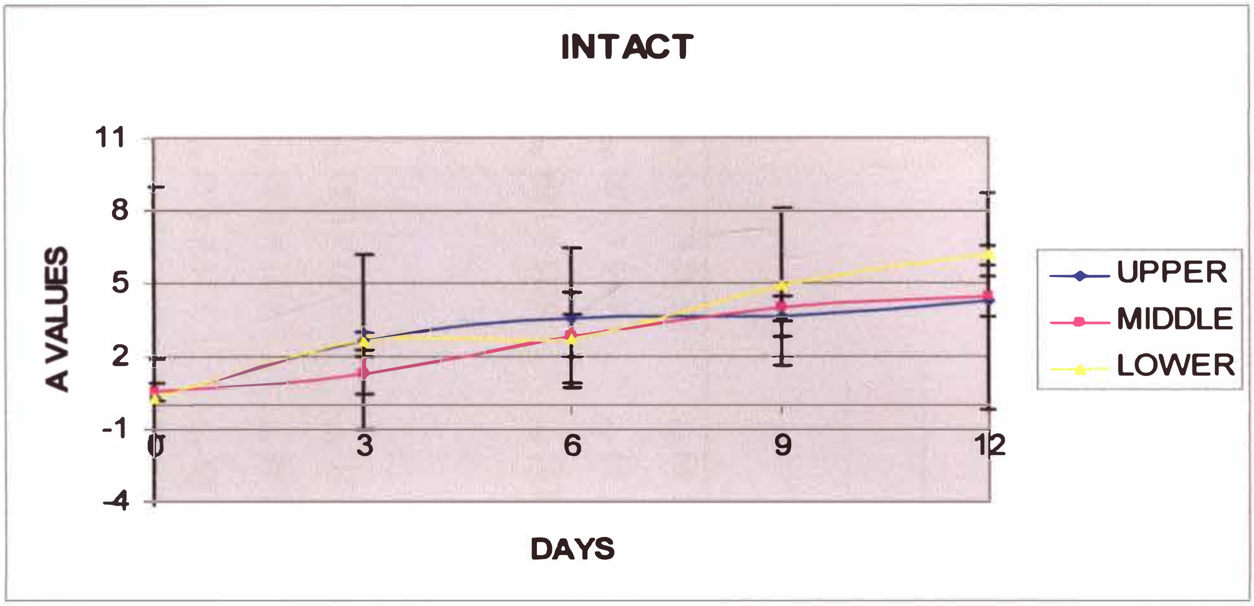
Note: Values in Table 4.8.1 are mean of 3 replicates means (n=3) ± Standard Deviation (3 readings/ replicate)
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

were into-related with those increased patterns as observed in peel color Hunter 'L' value (Figure 4.7.1), Hunter 'a' value (Figure 4.7.2) and 'b' values (Figure 4.7.3).

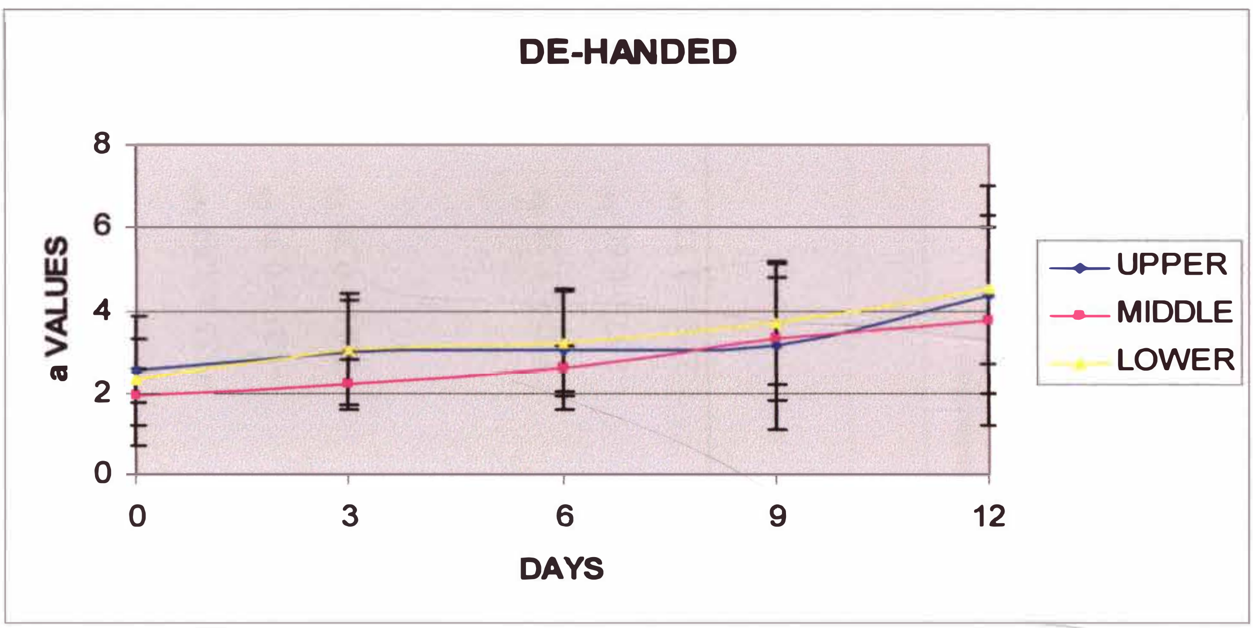
It is clearly shown on the Figure 4.8.1 that, both intact and de-handed bunches of bananas have a steady increased of pulp color (Hunter 'L' value) over storage days. There was no significant difference (P>0.05) observed in fruit pulp color (Hunter 'L' value) between different positions within a bunch of intact and de-handed bunches of bananas (Table 4.8.1).

According to Wainwright and Hughes, (1989), the pulp color of banana fruits were white creamy or pale yellow at index 1 or after harvest and then become yellowish when ripen. These changes were primarily due to degradation of cell color (white creamy) result from the degradation of starch to sugar (Marriott, 1980). Therefore the compositions of sugar (sucrose, glucose and fructose) lead to the conversion of yellowish pulp fruit as fruits ripen. (Chacon et al., 1987). It is also reported by Von Loesecke, (1950) that, the changes and rapid reduces of tannins and astringency as fruits ripen have contributed and correlated to the yellowish of pulp color.

Figure 4.8.2 (A) and (B) showed the effects of pulp color (Hunter 'a' value) for intact and de-handed bunches which have gradual increased in patterns over storage days. As for intact bunches, an increased in pulp color (Hunter 'a' value) was first observed by



(A)



(B)

Figure 4.8.2: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on 'a' Value Pulp Color of 'Berangan' Banana during Storage.

Banana.

Storage Conditions	Pulp Color (Hunter 'a' value)				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	-9.15 ± 8.72 Ba	-0.55 ± 3.59 ABa	1.14 ± 2.84 ABa	3.80 ± 0.83 ABa	7.19 ± 4.45 Aa
Middle	-13.91 ± 0.36 Da	-4.81 ± 0.74 Ca	-0.83 ± 0.84 Ba	3.10 ± 0.46 Aa	4.21 ± 0.85 Aa
Lower	-14.03 ± 1.58 Da	-5.64 ± 0.39 Ca	0.85 ± 1.83 Ba	4.48 ± 3.21 ABa	7.07 ± 0.42 Aa
De-handed Bunch					
Upper	1.51 ± 0.77 Aa	3.03 ± 1.28 Aa	3.57 ± 1.45 Aa	4.20 ± 2.01 Aa	5.25 ± 1.64 Aa
Middle	0.60 ± 0.69 Aa	1.57 ± 0.60 Aa	2.40 ± 0.55 Aa	3.23 ± 1.49 Aa	4.16 ± 2.52 Aa
Lower	2.01 ± 1.59 Aa	2.86 ± 1.37 Aa	3.17 ± 1.28 Aa	4.21 ± 1.49 Aa	5.32 ± 2.51 Aa

Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	NS

Note: Values in Table 4.8.2 are mean of 3 replicates means (n=3) ± Standard Deviation (3 readings/ replicate)
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

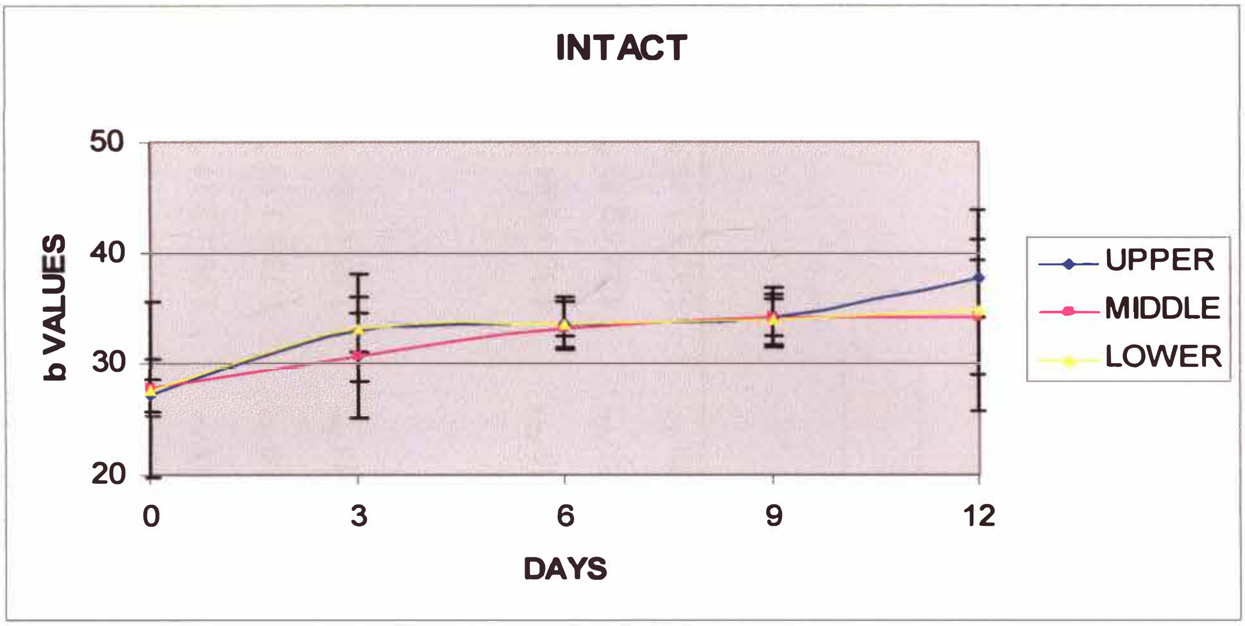
upper hands followed by lower hands and lastly middle hands. In comparison with de-handed bunches, an increased of fruit pulp color (Hunter 'a' value) was started by lower hands followed by upper hands and lastly lower hands. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches have shown continuous increased in fruit pulp color (Hunter 'a' value) which contributed to higher red and green color density and it was an indirect indication of fruits ripening. These patterns of fruit pulp color (Hunter 'a' value) increased were into-related with those increased patterns as observed in peel color Hunter 'L' value (Figure 4.7.1), Hunter 'a' value (Figure 4.7.2) and 'b' values (Figure 4.7.3).

It is clearly shown on Figure 4.8.2 that, both bananas form intact and de-handed bunches have a steady increased of pulp color (Hunter 'a' value) over storage days. There was no significant difference (P>0.05) observed in fruit pulp color (Hunter 'a' value) between different positions within a bunch of intact and de-handed bunches of bananas (Table 4.8.2).

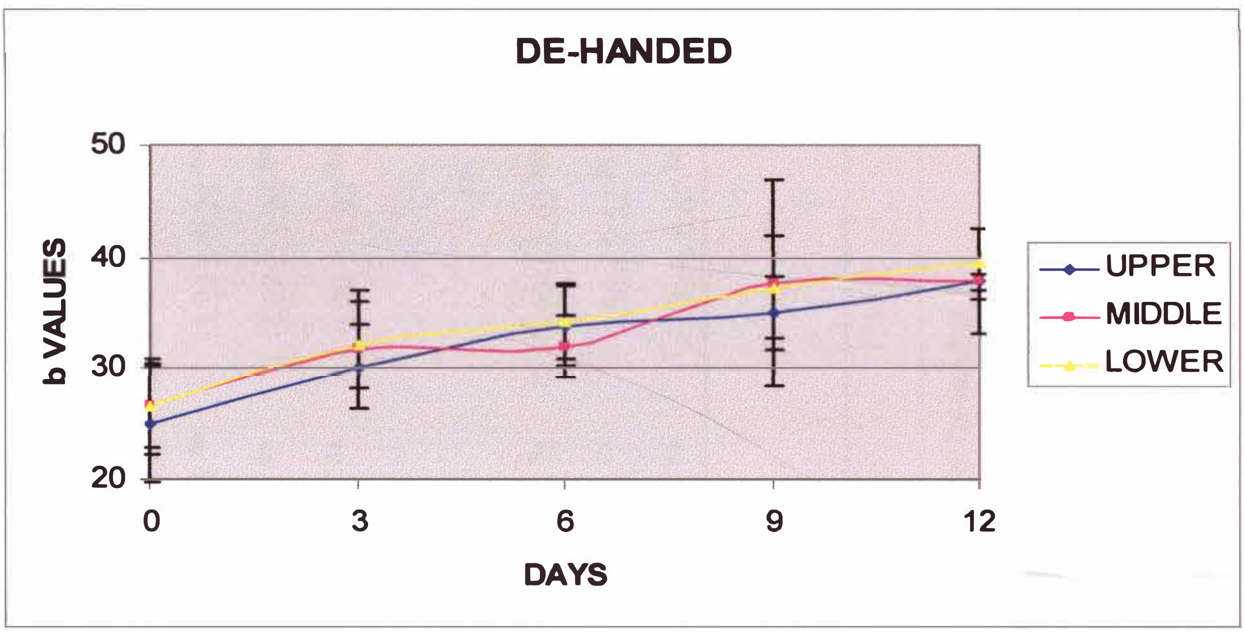
According to Gross et al., (1976) and Montenegro, (1988), the patterns of an increase in the Hunter 'a' value color for pulp is correspond and directly proportional with an increase in Hunter 'L' and 'b' values color. In other words, an increase in the value of Hunter 'L' also resulting in an increase in Hunter 'a' and 'b' values. The biochemical degradation of cell color continuously occurred as fruits ripen thus resulting in color changes as an indicator of fruits ripening is taking place (Lizada et al., 1983).

Figure 4.8.3 (A) and (B) showed the effects of fruit pulp color (Hunter 'b' value) for intact and de-handed bunches which have gradual increased in patterns over storage days. As for intact bunches, an increased in pulp color (Hunter 'b' value) was observed in upper hands followed by lower hands and lastly middle hands. In comparison with de-handed bunches, an increased of pulp color (Hunter 'b' value) was started by upper hands followed by middle hands and lastly lower hands. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches had shown continuous increased of pulp color (Hunter 'b' value) which contributed to an increased color density of yellow and blue color of bananas fingers and it was an indirect indication of fruits ripening. These patterns of fruit pulp color (Hunter 'b' value) increased were into-related with those increased patterns as observed in peel color Hunter 'L' value (Figure 4.7.1).

Hunter 'a' value (Figure 4.7.2) and 'b' values (Figure 4.7.3), and pulp color Hunter 'L' (Figure 4.8.1) and Hunter 'a' value (Figure 4.8.2) respectively. It is clearly shown on the Figure 4.8.3 that, both intact and de-handed bunches of bananas have a steady increased of pulp color (Hunter 'b' value) over storage days. There was no significant difference (P>0.05) observed in fruit pulp color (Hunter 'b' value) between different positions within a bunch of intact and de-handed bunches of bananas (Table 4.8.3). Hunter 'b' value has increase due to the increase of Hunter 'L' and 'a' values as ripening process takes place (Abd. Shukor et al., 1986, Gross et al., 1976; Montenegro, 1988).



(A)



(B)

Figure 4.8.3: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on 'b' Value Pulp Color of 'Berangan' Banana during Storage.

Banana.

Storage Conditions	Pulp Color (Hunter 'b' value)				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	1.45 ± 13.98^{Ba}	3.25 ± 0.24^{Aa}	3.53 ± 0.89^{Aa}	3.76 ± 1.47^{Aa}	3.99 ± 2.37^{Aa}
Middle	2.12 ± 1.53^{Ba}	3.28 ± 3.26^{Aa}	3.49 ± 2.01^{Aa}	3.59 ± 1.09^{Aa}	3.73 ± 1.95^{Aa}
Lower	2.20 ± 2.78^{Ba}	3.24 ± 1.92^{Aa}	3.46 ± 1.73^{Aa}	3.51 ± 1.83^{Aa}	3.58 ± 2.04^{Aa}
De-handed Bunch					
Upper	3.01 ± 2.83^{Ba}	3.22 ± 3.92^{ABa}	3.57 ± 6.52^{ABa}	4.03 ± 3.56^{ABa}	4.35 ± 5.44^{Aa}
Middle	3.28 ± 2.43^{Ca}	3.56 ± 2.52^{BCa}	3.80 ± 0.79^{ABCa}	3.95 ± 1.27^{ABa}	4.24 ± 2.57^{Aa}
Lower	3.27 ± 0.98^{Ba}	3.38 ± 0.67^{Ba}	3.61 ± 1.37^{ABa}	3.74 ± 1.78^{Aa}	3.87 ± 1.49^{Aa}

Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	NS

Note: Values in Table 4.8.3 are mean of 3 replicates means (n=3) ± Standard Deviation (3 readings/ replicate)
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

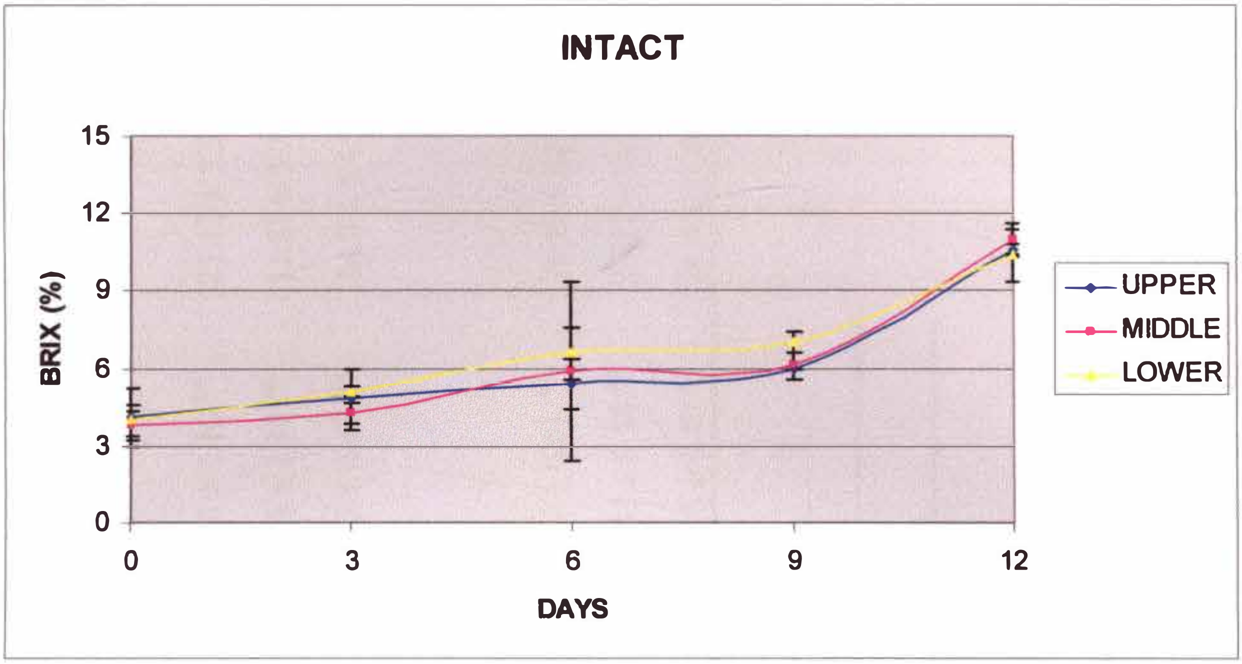
Therefore, all these Hunter values of 'L', 'a' and 'b' are directly proportional towards each others as fruit gets ripen.

4.9 Total Soluble Solids (TSS)

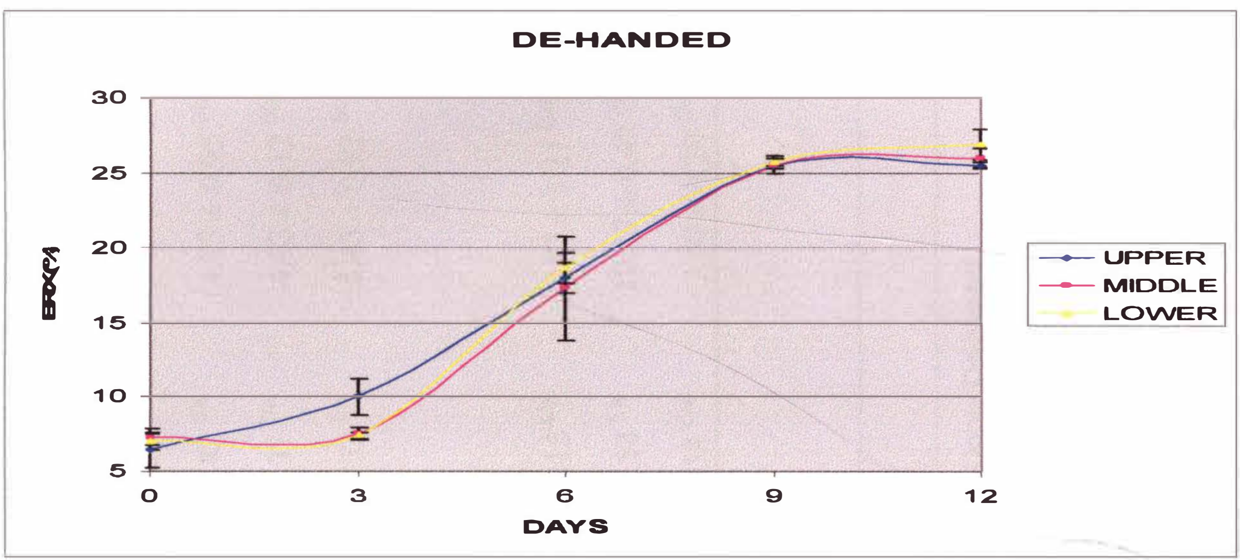
Figure 4.9 (A) and (B) showed the effects of total soluble solids for intact and de-handed bunches which had a gradual increased in patterns over storage days. The same trends were also reported by Singh et al., (1976) and Abdullah et al., (1987). As for intact bunches, an increase in the level of total soluble solids was started by the lower hands followed by middle hands and lastly upper hands. In comparison with de-handed bunches, an increased of the total soluble solids was started by upper hands followed by middle hands and lastly lower hands. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches have reach almost the same level of total soluble solids which contributed to synchronization in ripening process.

In term of total soluble solids level produced, it is clearly seen on Figure 4.9 that de-handed bunches of bananas have higher level of total soluble solids over storage with an average readings of about 25 ° Brix. In contrast, intact bunches of bananas only shown average readings of about 11 ° Brix over 12 storage days. Thus, faster conversion of starch to sugar occurred in de-handed bunches of bananas compared to the intact bunch of bananas. There were a highly significant differences ($P<0.05$) observed in total soluble solids between different positions within a bunch of intact and de-handed bunches of bananas (Table 4.9) where lower positions had higher TSS values over the storage, meanwhile in de-handed bunch, upper position showed the highest TSS (Table 4.9).

As reported by Will et al., (1983), the increase of sugar content in banana due to increase of starch hydrolysis during ripening process thus resulting in 15-30 % sugar enrichment in the ripe pulp. . As reported by Von Loesecke (1950), the total sugar and reducing sugar contents for green banana (upper, middle and lower positions) of index 1 are 1.32 and 0.52 percent and for banana grade 7 are 19.7 and 10.3 where sugar content increased over the day storage as also been shown and proved in this study. According to Will et al., (1983), sucrose has contributed about 11 % of sugar compositions, followed by glucose with approximately 3 - 4 % and lastly fructose.



(A)



(B)

Figure 4.9: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on Total Soluble Solids of 'Berangan' Banana during Storage.

Storage Conditions	Total Soluble Solids				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	4.33 ± 0.42^{Bb}	4.93 ± 0.95^{Bb}	5.47 ± 1.33^{Bb}	6.33 ± 1.10^{Bb}	21.13 ± 3.56^{Aa}
Middle	4.27 ± 0.31^{Ba}	4.93 ± 0.12^{Bb}	5.53 ± 0.95^{Bb}	6.33 ± 1.10^{Bb}	11.87 ± 3.23^{Ab}
Lower	4.60 ± 0.53^{Bb}	5.45 ± 0.92^{Bb}	6.33 ± 1.15^{Bb}	7.33 ± 0.42^{Bb}	14.0 ± 3.46^{Aab}
De-handed Bunch					
Upper	6.33 ± 1.15^{Cb}	7.87 ± 1.21^{Cab}	17.0 ± 1.0^{Bb}	26.0 ± 0.01^{Ab}	26.13 ± 0.23^{Ab}
Middle	8.67 ± 0.58^{Ca}	10.47 ± 0.42^{Ca}	17.0 ± 3.46^{Bb}	25.53 ± 0.50^{Ab}	27.27 ± 0.64^{Ab}
Lower	6.67 ± 0.58^{Cab}	7.40 ± 0.20^{Cb}	17.0 ± 1.0^{Bb}	25.13 ± 0.42^{Ab}	26.93 ± 1.01^{Ab}

Test of Significant	
Upper Intact Vs. Upper De-handed	*
Middle Intact Vs. Middle De-handed	*
Lower Intact Vs. Lower De-handed	*

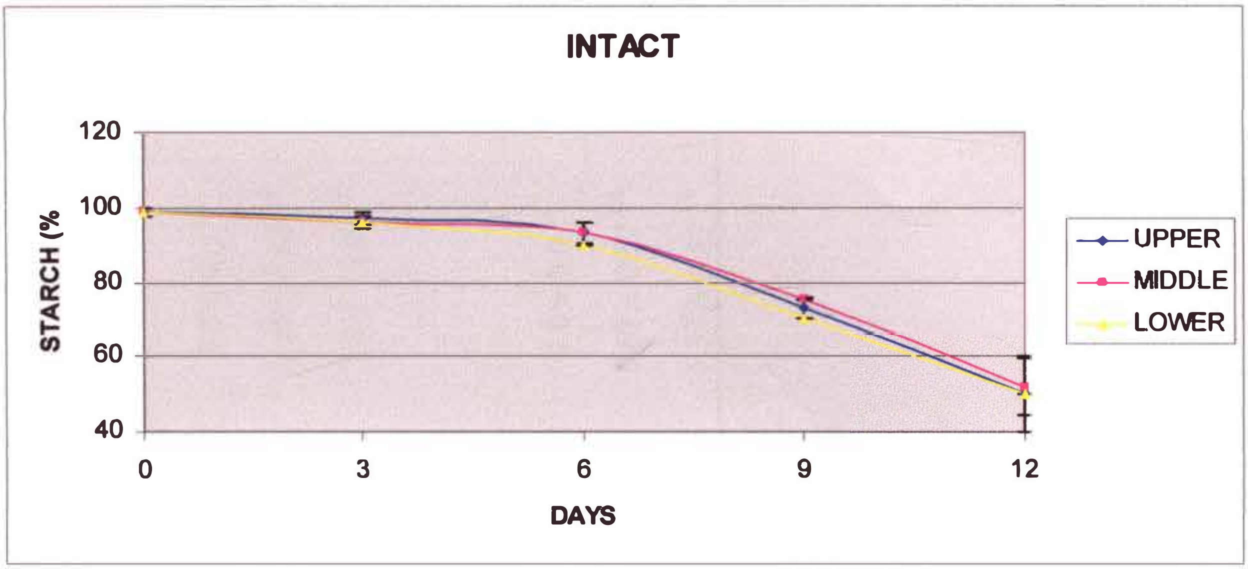
Note: Values in Table 4.9 are mean of 3 replicates means (n=3) ± Standard Deviation
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

4.10 Starch content

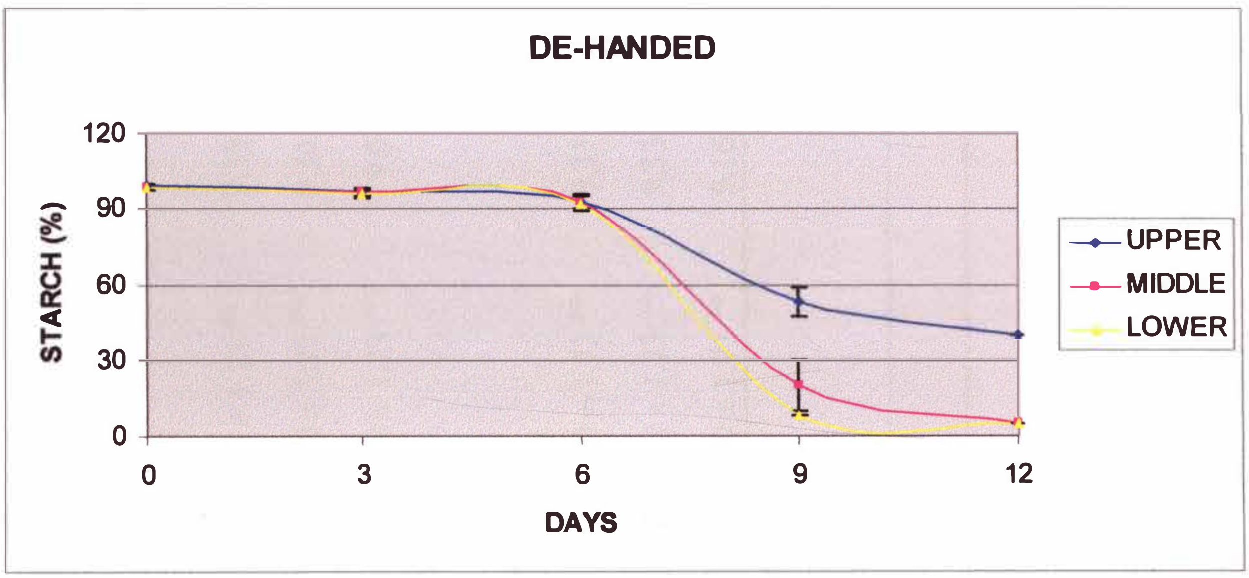
Figure 5.0 (A) and (B) showed the effects of starch content for intact and de-handed bunches which have gradual decreased in patterns over storage days. Both intact and de-handed bunches decreased in starch content started by lower hands followed by middle hands and lastly upper hands. At day 0, the starch content of both intact and de-handed bunches of bananas were almost the same.

However the rates of deceasing were not the same. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches had shown continuous decreased in starch content which contributed to higher accumulation of sugar (sucrose, glucose and fructose), an indirect indication of ripening process.

It is clearly shown in the Figure 5.0 that, both bananas of intact and de-handed bunches have shown a sharp decreased after day 6 and a clear comparison of starch content can be seen and referred to Appendix D. There was no significant difference (P>0.05) observed in starch content between different positions within a bunch of intact and de-handed bunches of bananas (Table 5.0). The starch comprising 85 to 95 % of dry matter of unripe pulp and degrades rapidly after the initiation of ripening process



(A)



(B)

Figure 4.10: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on Starch Content of 'Berangan' Banana during Storage.

Table 4.10: Effects of Different Positions within a Bunch of Intact and De-handed Bunches on the Starch Content of Berangan Banana.

Storage Conditions	Starch Content				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	9.86 ± 1.15^{Aa}	9.7 ± 1.73^{Aa}	9.33 ± 2.88^{Aa}	7.33 ± 2.8^{Bab}	5.0 ± 0.0^{Ca}
Middle	9.86 ± 1.15^{Aa}	9.60 ± 1.73^{Aa}	9.33 ± 2.88^{Aa}	7.50 ± 0.0^{Bab}	5.16 ± 7.63^{Ca}
Lower	9.86 ± 1.15^{Aa}	9.60 ± 1.73^{Aa}	9.0 ± 0.0^{Aa}	7.0 ± 0.0^{Bab}	5.0 ± 10.0^{Ca}
De-handed Bunch					
Upper	9.93 ± 1.15^{Aa}	9.70 ± 1.73^{Aa}	9.33 ± 2.88^{Aa}	5.33 ± 5.77^{Ba}	4.0 ± 0.0^{Ba}
Middle	9.86 ± 1.15^{Aa}	9.70 ± 1.73^{Aa}	9.33 ± 2.88^{Aa}	2.0 ± 10.0^{Bb}	5.67 ± 0.57^{Cb}
Lower	9.86 ± 1.15^{Aa}	9.60 ± 1.73^{Aa}	9.16 ± 2.88^{Ba}	8.0 ± 0.0^{Cb}	5.33 ± 0.57^{Cb}

Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	NS

Note: Values in Table 4.10 are mean of 3 replicates means (n=3) ± Standard Deviation
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level (P<0.05).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level (P<0.05).
NS = Not Significant
* = Significant

resulting in only 5 to 15 % of starch content in ripe banana pulp (Abdullah et al., 1987 and Abd Shukor et al., 1986).

According to Madamba et al., (1977), the increase in sugar content consequent to starch hydrolysis is the most striking chemical change during ripening in banana fruit. However, the mechanisms and enzymes involved were still not well understood.

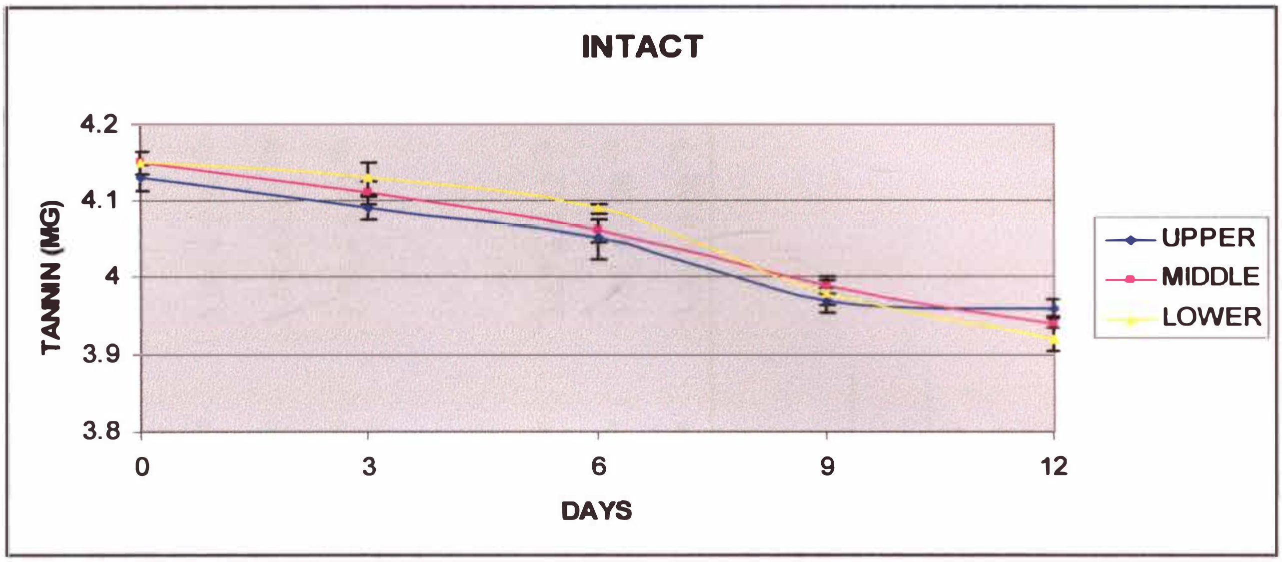
4.11 Tannin content

Figure 5.1 (A) and (B) showed the effects of tannin content for intact and de-handed bunches which have gradual decreased in patterns over storage days. Both intact and de-handed bunches decreased in tannin content started by upper hands followed by middle hands and lastly lower hands. However the rates of deceasing were not the same. A sharp decreased ware observed after day 6 of both intact and de-handed bunches of bananas. Towards the end of storage days, all three positions of hands in both intact and de-handed bunches had shown continuous decreased in tannin content which contributed to lesser taste of astringency in fruit which is an indirect indication of ripening process.

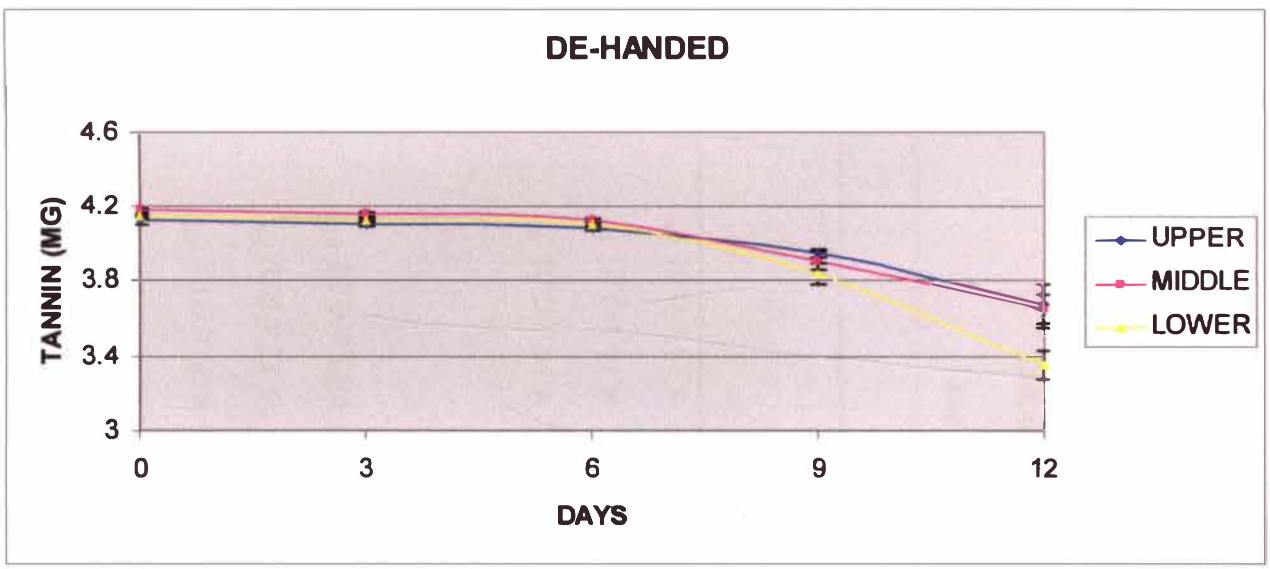
It is clearly shown in the Figure 5.1 that, bananas form intact bunches have a continuous sharp decreased started from day 0 compared to de-handed bunches. There was no significant difference (P>0.05) observed in tannins content between different positions within a bunch of intact and de-handed bunches of bananas (Table 5.1).

Tannin is one of the polyphenols which contribute to astringency taste in fruits (Goldstein and Swain, 1963, Joslyn and Goldstein, 1964, Ranganna, 1977, Ismail and Embong, 1984). Banana becomes astringent when in green or immature particularly during early stages of ripening (Von Loesecke, 1950). It is believed that decrease in astringency has correlated to decrease in tannin content in banana (Slocum, 1933).

During ripening of many edibles fruits, both tannin and astringency are reduced rapidly and the changes in astringency level are actually the reflection of changes that have occurred in the molecular size of tannins (Goldstein and Swain, 1963). Physiology of the astringency sensation was due to the interaction of these polyphenols with salivary proteins and glycoprotein (Goldstein and Swain, 1963). Effects of tannin on browning in fruit and fruit products (Swain, 1962) and cloudiness in fruit juices (Cash et al., 1976) have long been recognized.



(A)



(B)

Figure 4.11: Effect of Different Positions within a Bunch of Intact Bunch (A) and De-handed Bunch (B) on Tannin Content of 'Berangan' Banana during Storage.

Table 4.11: Effects of Different Positions within a Bunch of Intact and De-handed Bunches on the Tannin Content of Berangan Banana.

Storage Conditions	Tannin Content				
	Day 0	Day 3	Day 6	Day 9	Day 12
Intact Bunch					
Upper	4.13 ± 0.02^{Aa}	4.09 ± 0.02^{ABa}	4.05 ± 0.03^{Ca}	3.97 ± 0.02^{Ca}	3.96 ± 0.01^{Ca}
Middle	4.15 ± 0.02^{Aa}	4.12 ± 0.02^{Ba}	4.06 ± 0.02^{Ca}	3.99 ± 0.01^{Da}	3.94 ± 0.01^{Eab}
Lower	4.15 ± 0.02^{Aa}	4.13 ± 0.02^{ABa}	4.09 ± 0.01^{Ba}	3.98 ± 0.02^{Ca}	3.92 ± 0.02^{Db}
De-handed Bunch					
Upper	4.12 ± 0.02^{Ab}	4.10 ± 0.01^{Ab}	4.08 ± 0.01^{ABb}	3.95 ± 0.02^{Ba}	3.67 ± 0.12^{Ca}
Middle	4.18 ± 0.02^{Aa}	4.16 ± 0.01^{Aa}	4.12 ± 0.02^{Aa}	3.91 ± 0.05^{Ba}	3.65 ± 0.08^{Ca}
Lower	4.15 ± 0.01^{Aab}	4.13 ± 0.01^{Ab}	4.10 ± 0.01^{Aab}	3.84 ± 0.06^{Ba}	3.35 ± 0.08^{Cb}

Test of Significant	
Upper Intact Vs. Upper De-handed	NS
Middle Intact Vs. Middle De-handed	NS
Lower Intact Vs. Lower De-handed	NS

Note: Values in Table 4.11 are mean of 3 replicates means (n=3) ± Standard Deviation
A-D = Means bearing the same superscript within the same column are not significantly different at 5 % level ($P<0.05$).
a-d = Means bearing the same superscript within the same row are not significantly different at 5 % level ($P<0.05$).
NS = Not Significant
* = Significant

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

Fruit ripening processes were determined and observed through physico-chemical changes in terms of peel and pulp color, starch and tannins contents and total soluble solid (TSS) that occurred in the fruits. Therefore, from this study it was clearly seen based on the results from both intact and de-handed bunches of bananas which had undergone ripening process over 12 days of storage at ambient temperature. Both had shown different patterns of ripening behaviors in terms of total soluble solid (TSS) content, peel and pulp color and weight ratio, fruit weight, texture and volume, starch content and last but not least tannins content with respect to different positions (upper, middle and lower hands) and also between intact and de-handed bunches itself.

This study had proven that, maturation of fruits in a bunch starts from upper hands to the lower fruit hands for both intact and de-handed bunches of bananas. Nevertheless, the lower hands able to caught up the ripening process in terms of chemical changes such as total soluble solid, tannins and starch content where towards the end of storage day (day 12) the total soluble solid content as well as tannins and starch content had synchronized with those upper and middle hands although upper and middle hands have showed rapid changes in terms of physical aspect (color of peel). Besides, this study also showed that ripening process happened faster and more rapid in de-handed bunches compared to in intact bunches of bananas. This can be observed through physical changes such as fruits shape, skin color, fruit texture and nature of stylar end. The skin color of fruits changes from dark green in immature fruits (0-6 days) to yellow in mature fruits (6-12 days).

In term of chemical changes, both intact and de-handed bunches of bananas with respect to upper, middle and lower hands had showed gradual increased ($P>0.05$) in total soluble solid (TSS) and starch content whereas a decreased patterns ($P>0.05$) have been observed for tannins contents over storage days. Changes were mostly started or observed firstly occurred in upper hands; however ripening process was able to catch up by lower hands over storage days. The increased in total soluble solid was primarily due to starch degradation as ripening process takes place. This was also resulting in the decreased of tannin content which means less astringency taste of the fruit which actually due to the reflection of changes that have occurred in the molecular size of tannins

In term of physical changes, the same patterns of ripening behaviors have been observed in both intact and de-handed bunches of bananas. There were gradual increased observed in physical changes such as fruit volume ($P<0.05$), fruit size ($P>0.05$) and fruit peel to pulp color ($P>0.05$). These are primary due to rapid movement of water molecules towards pulp from peel and water is loss trough transpiration and osmotic forces from peel and pulp thus resulting in heavier weight and greater volume of banana. The degradation of green pigments (chlorophyll) to carotenoids (yellow) had contributed to the increased values of peel and pulp color over storage days. Decreased patterns were observed in fruit texture, changes in weight and peel to pulp weight ratio which was primarily due to movement of water osmotically from peel to pulp and less water is loss trough transpiration and osmotic forces from peel and pulp which have caused fruits become firmer and less changes in weight over storage days.

Although upper hands have developed earlier than those middle and lower hands, the middle and lower hands still capable to catch up ripening process. The physical changes are into-related with those chemical changes. Therefore, chemical changes will indirectly caused changes in physical characteristics of the fruits. This was clearly seen and proven where increase in accumulation of sugar was earlier and rapid in lower hand than upper hand and this scenario has causes changes in peel and pulp texture and color, thus synchronizing ripening behaviors of upper, middle and lower hands respectively.

Therefore from the results, it was proven that, bananas in de-handed bunches have undergone rapid changes in terms of chemical and also physiological characteristics compared to those intact bunches. Over 12 days of storage, bananas in de-handed bunches were found over ripen where no changes especially in sugar accumulation was recorded. In comparison with intact bunches, bananas were found still at the index maturity of 6 or 7 and still need a few days to fully ripen or over ripen as observed in de-handed bunches of bananas.

6.2 Recommendations

According to Abdullah et al., (1986); Munasque, (1987) and Gelido, (1986), ripening behaviors of fruits is a wide prospect to study and investigate. It involves a lot of parameters and analyses which have to be done in order to reveal the real ripening behaviors of fruit. Therefore, results from this study only provide basic important scientific data on ripening behaviors of bananas with respect to intact and de-handed bunches of bananas and also at different positions namely upper, middle and lower hands respectively. Thus, in order to get precise and accurate scientific data on bananas ripening behaviors, further study should include and focus on to analyses of banana titratable acidity (TA), pH changes, ascorbic acid, pectin content, ethylene production, respiratory rates, sensory evaluation and flavor changes of bananas respectively.

Besides, study can also be done on the physico-chemical changes of banana during fruit development, maturation and also storage. Other than that, the effect of different finger positions (upper and lower) within a bunch of intact and de-handed bunches with respect to different hand positions (upper, middle and lower) are also interesting to be studied.

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Appendix A

List of equipments, apparatus and chemicals

- Top Pan Balance Weight
- Texture Analyzer (Stable Mirco Systems, TA-XT Plus Analyzer)
- Minolta Chromameter (Model Cr 200 Trimulus Color Analyzer)
- Measuring cylinder (1 liter)
- Thread
- Ruler
- Muslim Cloth
- Atago Hand Refractometer Model 11, 0 - 50 % Brix
- Iodine Solution
- Potassium Iodide
- Methanol
- Ethanol
- Acetone
- Meta-hydroxydiphenyl Solution
- Sodium Tetraborate Solution
- Galacturonic Acid Solution
- Folin-Denis Reagent
- Saturated Sodium Carbonate Solution
- Sodium Tungstate
- Phosphomolybdic Acid
- Phosphoric Acid
- Anhydrous Sodium Carbonate
- Tannic Acid Standard Solution
- Carton Box
- Poly Bag

- Volumetric Flask.
- Distilled Water/Deionized Water
- Knife
- Blender
- Test Tubes
- Beakers
- Refrigerator
- Filter Papers

Appendix B

Pictures of apparatus and equipments used

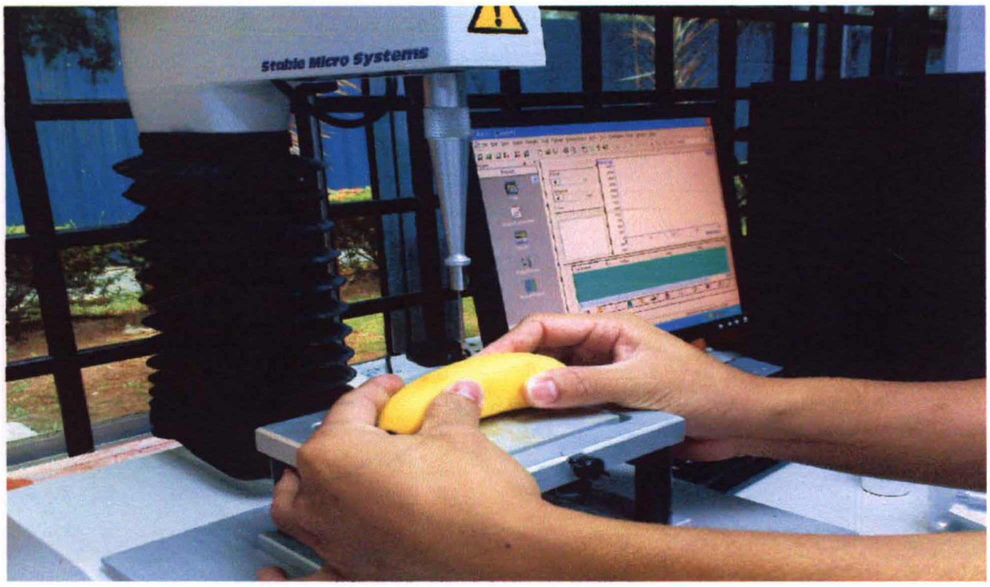


Figure 1: Performing texture analyzing (peel and pulp firmness)

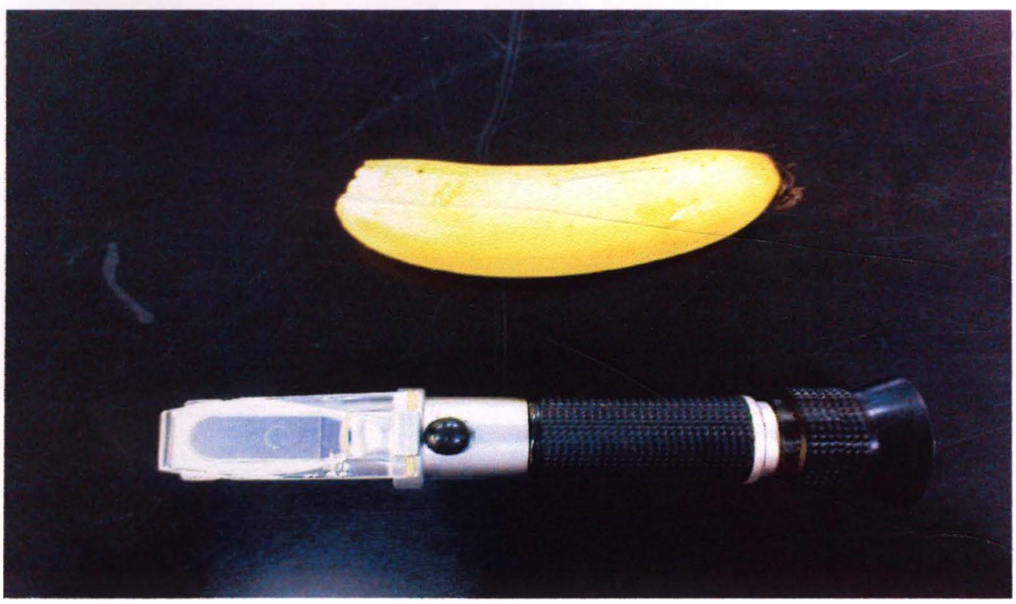


Figure 2: Performing analysis of Total Soluble Solid (TSS) with Refrectometer

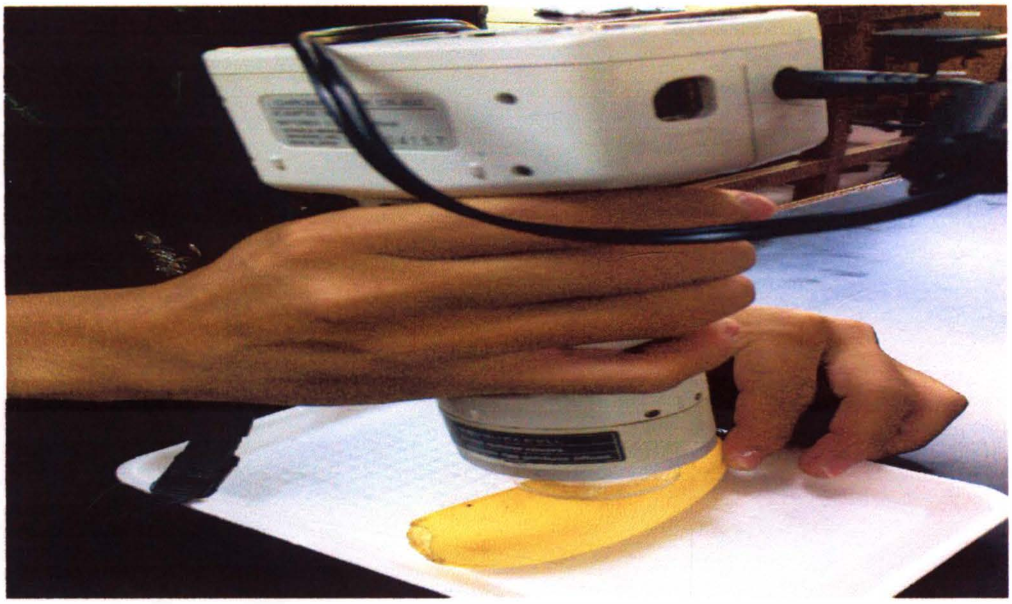


Figure 3: Performing color analysis (peel and pulp color) with colorimeter

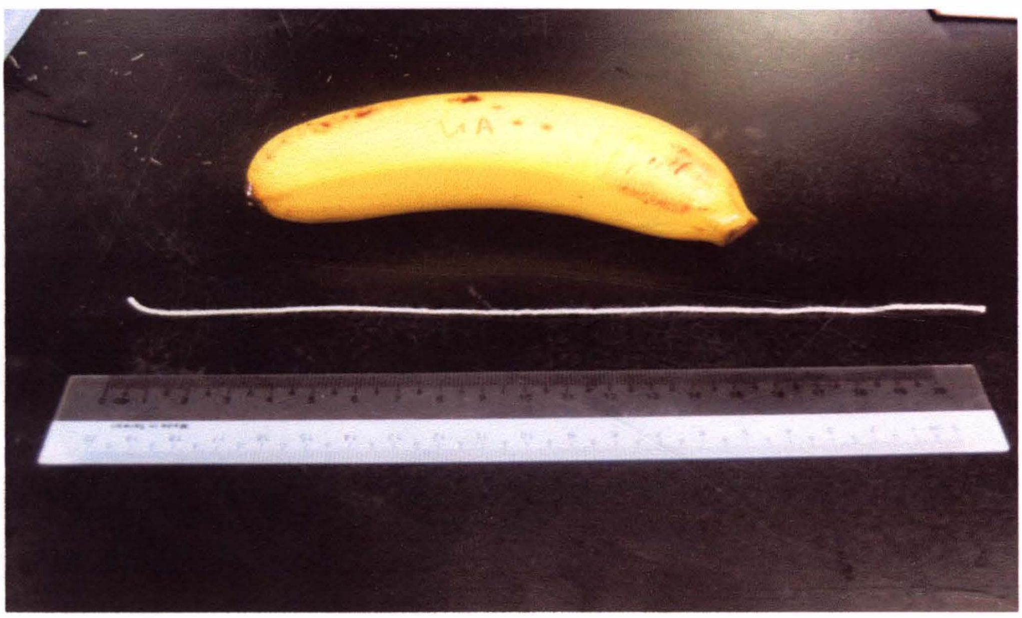


Figure 4: Measurement of fruit size (Length to diameter ratio)

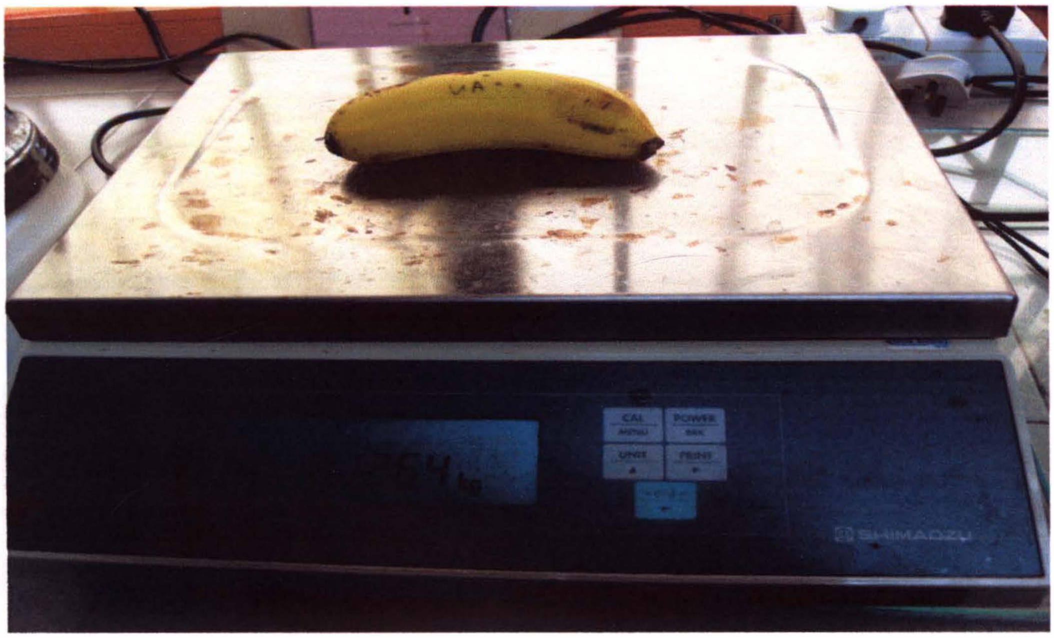


Figure 5: Weighing fruit sample for changes in weight

Figure 6: Weighing the fruit peels

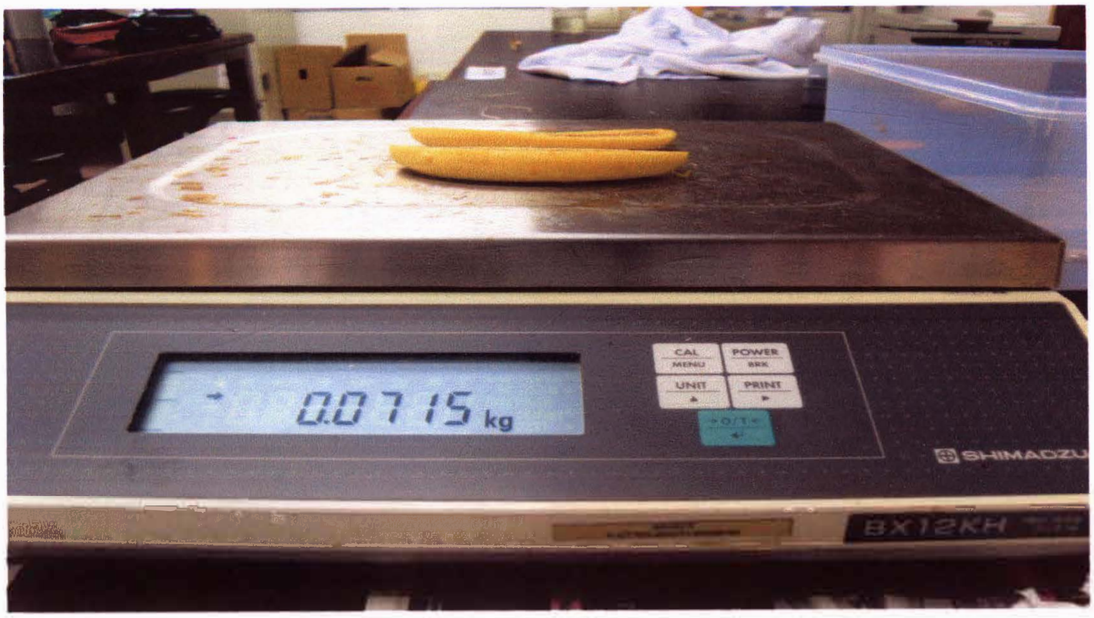


Figure 7: Weighing fruit pulps

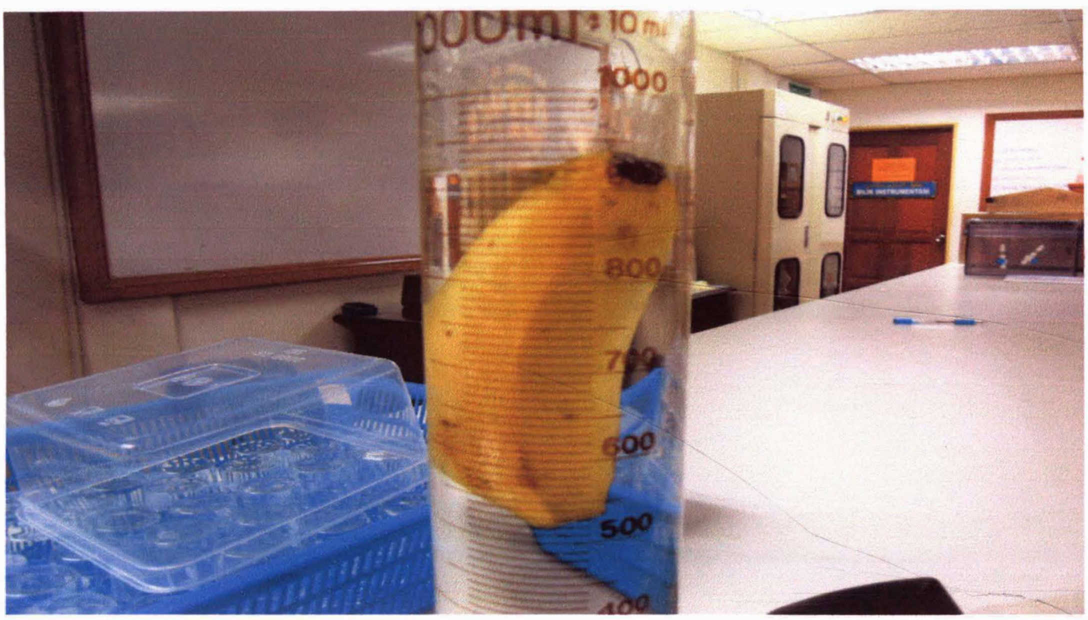


Figure 8: Measuring fruit volume with measuring cylinder

Figure 9: Conducting starch content analysis

Figure 10: Conducting Tannin content analysis

Appendix C

Observation of bananas (intact and de-handed bunches) over 12 storage days

DAY 0

Intact Bunch

De-handed Bunch

DAY 3

Intact Bunch

De-handed Bunch

DAY 6

Intact Bunch

De-handed Bunch

DAY 9

Intact Bunch

De-handed Bunch

Day 12

Intact Bunch

De-handed Bunch

Appendix D

Starch analysis (Intact and de-handed bunches) over 12 days storage

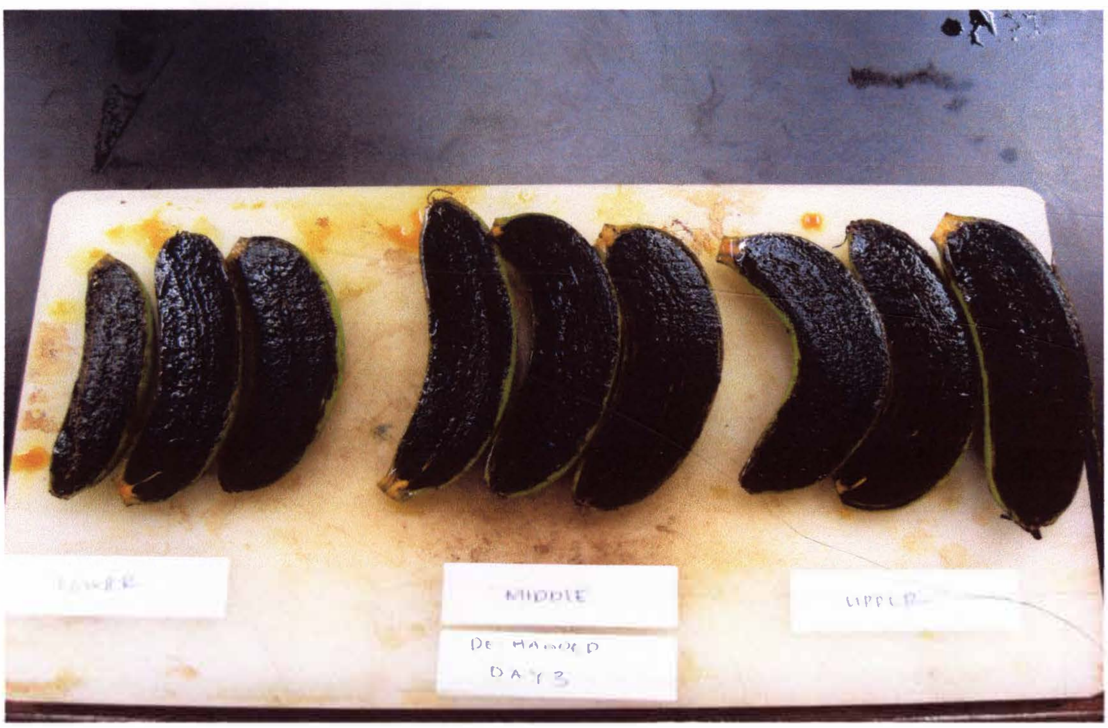
DAY 0

INTACT

DE-HANDED

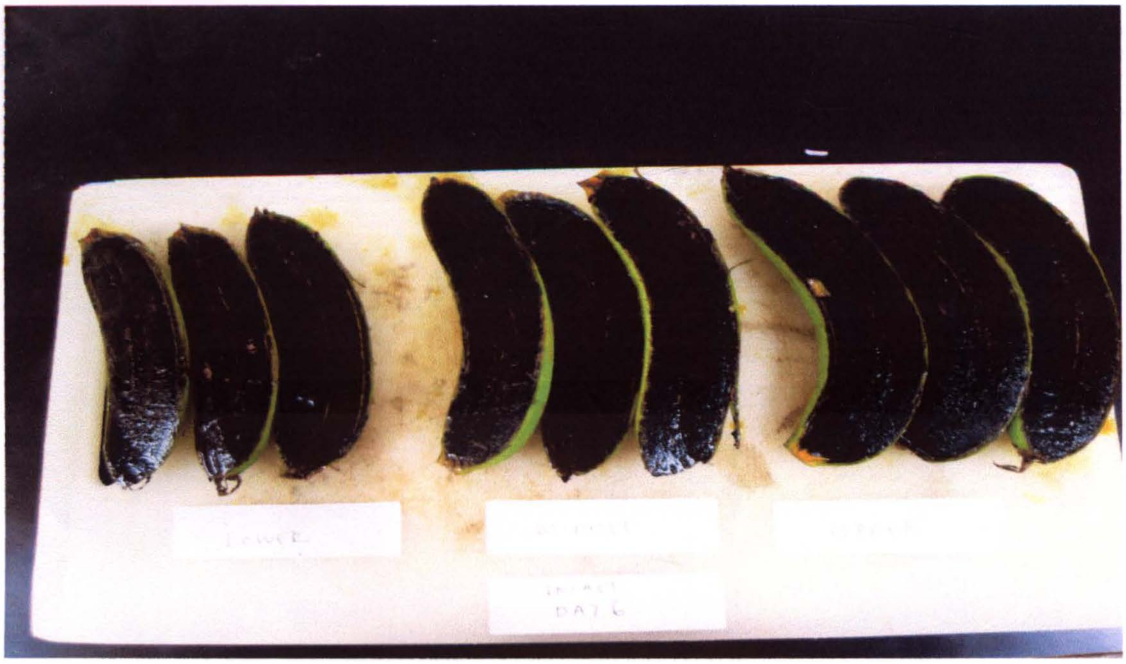
DAY 3

INTACT



DE-HANDED

DAY 6



INTACT

DE-HANDED

DAY 9

INTACT

DE-HANDED

DAY 12

INTACT

DE-HANDED

CURRICULUM VITAE (CV)

PERSONAL DETAILS

Name	: JAMES JAM ANAK JOLLY
Matric Number	: UK14747
I.C Number	: 870816-52-6021
Resident Address	: House 215-4, Block B2, Universiti Malaysia Terengganu (Tel: 0179338556)
Permanent Address	: S/L 5042 RPR Bandar Baru Permyjaya Tudan, 98000 Miri Sarawak. (085-663453)
E-mail	: jamesjamjolly@yahoo.com.my
Mobile	: 0179338556
Date of Birth	: 16th August 1987
Age	: 23 years old
Gender	: Male
Marital Status	: Single
Health	: Excellent
Race	: Iban
Religion	: Christian
Nationality	: Malaysian
Height/ Weight	: 164cm/64kg
Hobbies/Interest	: Reading and Jogging
Language (Written)	: Malay (Excellent)/English (Good)
Language (Spoken)	: Malay (Excellent)/English (Good)

EDUCATIONAL BACKGROUND

2007-Now : Bachelor of Applied Science of Agrotechnology (Post Harvest Technology) at Malaysian University of Terengganu (UMT)

GPA SEM 1	: 3.52
GPA SEM 2	: 3.90
GPA SEM 3	: 3.71
CPA SEM 4	: 3.45
GPA SEM 5	: 3.74
CGPA	: 3.66

2005-2006 : Sekolah Menengah Kebangsaan Lutong Miri Sarawak
STPM (Sijil Tinggi Pelajaran Malaysia)
CGPA: 2.60

2003-2004 : Sekolah Menengah Kebangsaan Lutong Miri Sarawak.
(Science Stream) SPM (Sijil Pelajaran Malaysia) :(3A, 7B)

2000-2002 : Sekolah Menengah Kebangsaan Lutong, Miri Sarawak.
Penilaian Menengah Rendah (PMR) : (4A, 3B)

KNOWLEDGE AND SKILL

- Skill and techniques in debating
- Good knowledge in Genetic and Biotechnology of Agriculture, Crop Production, Animal Anatomy and Physiology, Agroecosystem, Food and Crop Production Technology, Basic of Biochemistry, farm management, Agricultural Economic, Business , Post Harvest Treatment and Storage, Cold Chain Management, Unit Operation and Post Harvest Handling Biostatistics and Basic Livestock
- Good knowledge in Post Harvest Physiology, Agriculture Economy, Basic Microbiology and Post Harvest Technology and Handling
- Skill in word programmer, power point, excel and basic in SPSS software
- Skill in handling HPLC, GC, UV Spectrometer and others laboratory equipments.

WORKING AND OTHER EXPERIENCES

Mac-April 2006 : Worked as a temporary teacher at Sekolah Rendah Kebangsaan Lutong Miri Sarawak for subjects Science, Mathematics and English.

May-July 2009 : Underwent two months internship at Curtin University of Technology in Perth Western Australia.

April-May 2010 : Research assistant under Dr. Noraznawati (FST)

CAREER OBJECTIVES

-To develop Agrotechnology (Post Harvest Technology) sector.
-To applied the Post Harvest Technology in Agriculture.

CURRICULUM ACTIVITIES

1. Activities Involvement In Campus

ACTIVITY/PROGRAM	ACHIEVEMENT/POSITION
1. UMT Vice Chancellor Parliamentary Debate 2008	Winner/Debater
2. Dance Competition In Conjunction With UMT Cultural Festival 2007	Winner/Dancer
3. MPP Theater Competition 2008	Third Place/Director
4. Debate Intellectual Club 07/08	Vice Presiden 3
5. MPP Academic Quiz 2008	Third Place
6. Independence Day Run 2007	Contestant
7. December Dean List 2007/2008	Receiver
8. July Dean List 2007/2008	Receiver
9. December Dean List 2008/2009	Receiver
10. Debate Intellectual Club 2009	Vice President 1

2. ACTIVITIES INVOLVEMENT OUTSIDE CAMPUS

ACTIVITY/PROGRAM	ACHIEVEMENT/POSITION
1. Royal Intervarsity Debating Championship 2008	Preliminary round/debater
2 Integrity Intervarsity Debating Championship 2008	Preliminary round/debater
3 Environmental Intervarsity Debating Championship 2008	Preliminary round/debatar
4 Independent Parliamentary Intervarsity Debating Championship 2008	Preliminary round/debater
5. Royal Intervarsity Debating Championship 2009	Preliminary round/debater
6. Sabah and Sarawak Christian Federal 2008	Vice President
7. University Darul Iman Malaysia, Inter-college Debating Championship 2009	Judge
8. Environmental Intervarsity Debating Championship 2010	Preliminary round/debater

3 INVOLVEMENT IN CLUB PROGRAM

ACTIVITY/PROGRAM	ACHIEVEMENT/POSITION
1. Hevotech Family Day 2007	Contestantt
2. Hevotech Family Day 2008	Place Management and Instrunents In-charger
3. Hevotech Club Dinner 2008	Transportation In-charger
4. Debate Club Family Day 2008	Program Director
5. Debate Club Aidilfitri Celebration 2008	Program Director
6. Debate Intellectual Club Birthday Party Celebration	Program Director

2005-2006 : Head Prefect of Sekolah Menengah Kebangsaan Lutong
: School debater (Sekolah Menengah Kebangsaan Lutong)
: School Hockey Player (Sekolah Menengah Kebangsaan Lutong (First Runner-Up MSSM 2006)

ACADEMIC REFERENCE

Madam. Zawiah BT Abdullah,
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Madam Rozita Binti Jayus (Student Affair centre)
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Terengganu Darul Iman.

THE EFFECT OF BANANA POSITIONS WITHIN A BUNCH ON THE RIPENING BEHAVIOR OF MUSA ACUMINATA CV. BERANGAN - JAMES JAM ANAK JOLLY