STUDIES ON POSTHARVEST QUALITY OF 'BUOI' MANGOES DURING COLD-STORAGE

A thesis submitted in partial fulfilment
of the requirements for the degree of

Master of Applied Science

in

Agricultural Engineering

at

Institute of Technology and Engineering

Massey University

Palmerston North, New Zealand

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1998

VIETNAM

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Myanmar (Burma)
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Dong Van
Ha Giang
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Haiphong
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Tra Vinh
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Soc Trang
Ca Mau
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Con Son
Cu Lao Thu
Dao Phu Quoc (Vietnam)
Ko Chang
Ko Mak
Ko Kut
Gulf of Thailand
South China Sea
Yu Jiang R.
Black R.
Red R.
Mekong R.
Chi R.
Mun R.
Kong R.
Srepok R.
Tonle Sab R.
22°
18°
14°
10°
104°
108°
0 150 km
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Tien Giang Province

Mango (*Mangifera indica L.*) - King of Oriental Fruits

ABSTRACT

The objective of this thesis was to characterise the postharvest quality attributes of 'Buoi' mangoes by: (1) providing a detailed review of the literature on postharvest handling and storage of mangoes; (2) studying the effects of harvest date, storage temperature, length of storage, and postharvest treatments on postharvest quality of 'Buoi' mangoes; and (3) developing regression models for predicting postharvest quality attributes of 'Buoi' mango fruit as a function of storage temperature and length of storage.

A review of the literature showed that considerable research has been carried out during the last 20 years on several aspects of postharvest handling and storage of mangoes. The literature review included maturity assessment, ripening behaviour of mangoes at low temperature storage, and postharvest treatments for controlling diseases and disorders. Many researchers have recommended storage conditions and postharvest treatments for various mango cultivars such as 'Alphonso', 'Carabao', 'Kensington', 'Haden', 'Keitt', 'Kent' etc., however, there was a dearth of information on the storage requirements for the important cultivars grown in Vietnam.

Samples of 'Buoi' mango grown in Hoa Loc area, Cai Be District, Tien Giang Province (latitude: 10° 5', longitude: 102°), Vietnam, were harvested at commercial maturity on three harvest dates based on uniform peel colour and morphological characteristics such as size and shape and transferred to laboratory at the Postharvest Technology Institute (PHTI) in Hochiminh city. To study the effects of harvest date on mango quality, fruit samples from the three harvests were stored at 12 ± 1°C (RH 85-90%) for 25 days. At 5-day intervals, sub-samples were randomly removed from cold storage and assessed for weight loss, peel and pulp colour, soluble solids content (SSC), total acidity, flesh firmness and crushing stress, chilling injury (CI) and eating quality. Another sub-sample was assessed after 4 days ripening at 25°C. The results showed that increasing storage time led to a significant (P <

0.05) increase in weight loss, peel and pulp colour development, and incidence of chilling injury. However, both fresh firmness and crushing stress, and total acidity declined during storage. Soluble solids content and eating quality increased up to around 20 days, but declined afterwards.

Harvest date influenced weight loss, CI and fruit texture (both firmness and crushing stress), but did not affect peel and pulp colour, SSC, total acidity, and eating quality. Early harvested fruit lost more weight compared with the mid- and late harvested fruit. However, there was no significantly difference in weight loss between mid- and late harvested fruit. Up to 10 days storage, fruit texture in early harvested fruit was significant higher than in mid- and late harvested fruit, but after this period the difference disappeared. Early harvested fruit were more susceptible to CI than mid- and late harvested fruit. Compared to fruit kept in cold storage, fruit ripened at 25°C had higher SSC but were lower in total acidity. In addition, ripening fruit at 25°C increased the severity of CI.

To study the effects of storage temperature on mango quality, fruit samples from second harvest were stored at 7, 12, 17 ± 1°C (RH 85-90%), and room temperature (27°C, RH 75-85%) for 25 days. Storage temperature had a significant effect on fruit quality attributes. Increasing storage temperature led to increase in weight loss, and yellow colour development in peel and pulp tissue; however, firmness, crushing stress, total acidity and incidence of CI declined. In cold-stored fruit, soluble solids content and eating quality increased with increase in storage temperature. Storing fruit at 12°C up to 20 days and 17°C up to 15 days, respectively, maitained the quality and minimized the incidence of postharvest disorders in 'Buoi' mangoes. Regression models for predicting postharvest quality attributes of 'Buoi' mangoes as a function of storage temperature and storage time were developed, applicable for fruit storage in the range 7 - 27°C up to 15 days and 7 - 17°C up to 25 days.

To assess the effect of hot water treatment (HWT) for controlling of postharvest diseases and disorders in 'Buoi' mango, fruit samples were randomly assigned to the following treatments prior to cold storage at 12 ± 1°C (RH 85-90%): treatment 1 = fruit dipped in hot water at 52°C for 5 min; treatment 2 = fruit dipped in hot water at 52°C for 10 min; treatment 3 = fruit placed in PVC plastic bag; and treatment 4 = control (untreated) fruit. After 24 days storage, fruit were removed from cold storage and assessed for weight loss, peel and pulp colour, SSC, anthracnose, stem-end rot, shrivel and CI. HWT at 52°C for 5 or 10 min significantly reduced the incidence of anthracnose, stem-end rot and CI compared to fruit in plastic bag or untreated fruit. Fruit in plastic bag lost less weight than the other treatments. HWT at 52°C for 5 min was recommended for reducing the incidence of anthracnose, stem-end rot and CI in Vietnamese 'Buoi' mangoes.

ACKNOLEDGEMENTS

I would like to express my gratitude to my chief supervisor, Dr. Linus U. Opara for his valuable advice, supervision and support throughout this study. My sincere thanks are also given to Associate Prof. Cliff J Studman, my co-supervisor, for his important suggestions and kind assistance during investigation, especially his guidance at beginning of this project. My special thanks to Prof. Gavin L. Wall, Head of the Department for his permission to use Departmental fruit quality measurement equipment during my experiments in Vietnam.

I would also like to thank Prof. Le Van To, Director of Postharvest Technology Institute (PHTI), Hochiminh City, Vietnam for his useful advice and financial support during the time I carried out the experiments at his Institute.

Thanks are also due to the following who contributed to this study:

Prof. Pham Van Lang , Director of the Vietnam Institute of Agricultural Engineering, Hanoi, Vietnam for his advice and supervision during my experiments in Vietnam;
Ms. Bay, Researcher at Long Dinh Fruit Research Centre, for field assistance in obtaining fruit samples;
Mr. and Mrs. Tam, Hoa Loc area, Cai Be District, Tien Giang Province, Vietnam, for their permission to collect fruit from their commercial orchard.

My special thanks to all the staff and postgraduate students in the Department of Agricultural Engineering for their assistance and encouragement.

Finally I would like to thank NZODA for travel assistance and award of a Postgraduate Scholarship.

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LIST OF ABBREVIATIONS

ANOVA	= analysis of variance
a	= blade radius, m
b	= blade width, m
CA	= controlled atmosphere
CI	= chilling injury
CO_2	= carbon dioxide
EQ	= eating quality
HHHA	= high humidity hot-air
HI	= hyperthermal injury
HWT	= hot water treatment
ISFV	= International Standardisation of Fruits and Vegetables
ISO	= International Standard Organisation
k	= coefficient of individual acid
M	= maximum moment produced when the aim is horizontal
MA	= modified atmosphere
MAP	= modified atmosphere packaging
min	= minutes
n	= amount of NaOH 0.1 N
O_2	= oxygen
P	= weight of the sample
PE	= pectinesterase
PG	= polygalacturonse
RH	= relative humidity
R^2	= regression coefficient
SAS	= statistical analysis system
sec	= seconds
SSC	= soluble solids content
T	= storage time
TA	= total acidity
Temp.	= temperature

VHT	= vapour heat treatment
Wr	= weight loss rate
Wi	= initial weight
Wa	= weight after removal from cold storage
σ_{cr}	= flesh crushing stress

CHAPTER 1

GENERAL INTRODUCTION

1. Introduction

Mango is one of the most important fruit in Vietnam and other tropical countries. The mango industry in Vietnam has grown rapidly in recent years with total production over 152,000 tonnes in 1995 (Vietnam Publishing Statistical House, 1996). Although some cultivars grown in Vietnam such as 'Buoi', 'Cat Hoa Loc' and 'Thom' (Figure 1.1) are renowned for their excellent quality, export marketing of fresh mango fruit is non-existent in comparison to about 10% of total world production that is exported (FAO, 1994).

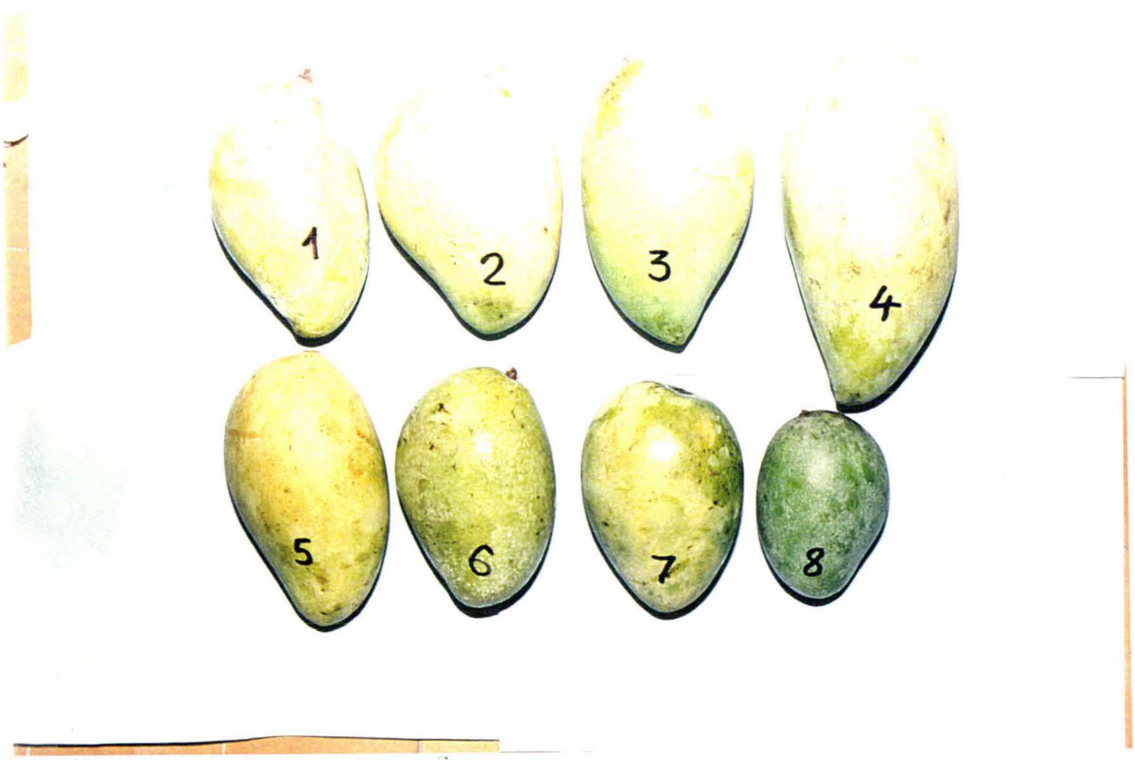

Figure 1.1 Different mango cultivars in Vietnam: 1) 'Buoi'; 2) 'Cat Chu'; 3) 'Cat Hoa Loc'; 4) 'Tuong'; 5) 'Thom'; 6) 'Xiem'; 7) 'Hon'; 8) 'Saigon'.

Current postharvest handling and storage system of mangoes in Vietnam is shown in Figure 1.2:

Harvesting

↓

Field Sorting & Packaging

↓

Transport

↓

Wholesale or Local Markets

↓

Sorting and Packaging

↓

Transport

↓

Local and Regional Markets

Figure 1.2 Current postharvest handling system of mangoes in Vietnam.

1) Harvesting: green mature fruit with a trace of yellow around the stem are harvested by hand or by a pole having cloth bag with cutting knife;
2) Field sorting and packaging: selected fruit without disease or damage are placed in baskets lined with paper to minimized physical injury (Figure 1.3);
3) Transport from orchard to local markets or to wholesalers: normally growers have no packhouse, therefore after picking they transport fruit to local markets or to wholesalers by motobikes or boats;

Figure 1.3 Packaging of mango fruit in local market.

4) Wholesaler: sorting, grading and packaging in baskets lined with paper. There are no postharvest treatments or cold storage facilities. After sorting and grading first class fruit is immediately transported by lorries to big cities and second class fruit are sold in local markets.

Several factors related to fruit physiology and lack of application of appropriate postharvest technologies preclude Vietnamese mango growers from participating in the growing world export market. These contributing factors are discussed below.

Postharvest storage technology

Mango is a climacteric fruit with very high respiration rates. The rate of deterioration (perishability) of harvested commodities is generally proportional to their respiration rate. Mango is mainly grown in tropical and sub-tropical countries with very high ambient temperatures (sometimes up to 35°C or higher), a condition which accelerates the rate of deterioration. Normally Vietnamese mangoes can be kept at room temperature (≈ 27°C) about 1 week to 10 days with acceptable quality. In general, shelf-life of fresh mangoes or other commodities can be prolonged by lowering storage temperature (Kader, 1992; Hardenburg et al., 1986). Currently, research on the application of cold-storage technology to mango is severely limited in Vietnam. This situation has therefore limited the development of export mango industry, including intra-regional mango trade due to poor storage life under existing postharvest handling practices.

Postharvest diseases and physiological disorders

Mangoes are highly susceptible to diseases such as anthracnose and stem-end rot, and physiological disorders such as spongy tissue and soft-nose. These diseases and disorders adversely affect fruit quality and also reduce the shelf-life. In addition, most importing countries require fresh mangoes that are free from pests and diseases. Therefore, there is a need for the Vietnamese mango industry to apply technologies of postharvest treatments to prolong fruit shelf-life for long term marketing and supply of top quality fruit to consumers.

2. Research Objectives

The overall aim of this study was to characterise the postharvest quality attributes of 'Buoi' mango which is the major cultivar grown in Vietnam.

The specific objectives were to:

- Conduct an extensive review of the literature on postharvest handling and storage of mango;

- Investigate the effects of harvest date, storage temperature and postharvest treatments on quality of 'Buoi' mangoes during cold storage; and

- Develop regression models for predicting postharvest quality attributes of 'Buoi' mangoes as a function of storage temperature and length of storage.

CHAPTER 2

LITERATURE REVIEW ON POSTHARVEST HANDLING AND STORAGE OF MANGO

2.1 Introduction

Mango (*Mangifera indica* Linn.) is one of the most important fruits of the tropical and subtropical regions of the world (Chadha and Pal, 1993; Medlicott et al., 1986). The mango is believed to have originated in the Indo-Burma region (Chadha and Pal, 1993; Kostermans and Bompard, 1993; Singh, 1960).

It is evident that the mango is now being grown in more than 100 countries spread over five continents, including relatively cold subtropical environments such as Israel and Spain (Sauco, 1993). World mango production in 1993 was estimated to be over 17.7 million tonnes which is mainly produced in the developing countries of the tropics. It is considered to be the most important fruit of Asia and currently ranks fifth in total production among major fruit crops, world-wide, after *Musa* (bananas and platains), *Citrus* (all types), grapes and apples (FAO Production Yearbook, 1993).

India is the major mango growing country of the world with 60.5% of the world production (Chadha and Pal, 1993). Other major producing countries are Mexico, Pakistan, Indonesia, Brazil, Thailand, the Philippines, China, Haiti, and South Africa (Chadha, 1989; Sauco, 1993). Mango is also grown commercially in some developed countries, for instance, in parts of the United States such as Florida and Hawaii, Israel, Australia and Spain (Campbell and Campbell, 1993; Chadha, 1989; Sauco, 1993). The principal exporters are the Philippines, Thailand, Mexico, and India and the minor exporters being Brazil, South Africa, Venezuela, Florida (USA), Cuba, Pakistan, Haiti, Israel, Trinidad, and Egypt (Chadha, 1989; Sauco, 1993).

Mango fruit is important as part of a healthy diet due to its unique, excellent taste and high vitamin (vitamin A - 2.4 mg/100g; and vitamin C - 30 mg/100g) and mineral contents (Sauco, 1993; Tucker, 1993). Salunkhe and Desai (1984) reported that ripe mangoes are also fair sources of thiamine, niacin, calcium and phosphorus.

Although there are many mango cultivars, only a few of them are commercially important (Krishnamurthy and Subramanyam, 1973); for example, there are nearly 1000 mango cultivars in India, but only about 20 cultivars are grown on commercial scale. In different countries, the export cultivar is only one or two, for instance, Alphonso from India; Carabao from the Philippines; Haden, Keitt and Zill from South Africa; Haden and Maya from Israel; Julie from Trinidad; Apple, Boribo and Nqowe from Kenya; Haden and Manila from Mexico; Okrang from Thailand; and Madame Francis from Haiti (Chadha, 1989).

The international demand for fresh mango fruit is increasing steadily, particularly from Europe, North America, and Japan. Europe import increased from 18,584 tonnes in 1985 to 40,951 in 1990 while the United States imported 59,176 tonnes in 1990 compared with 38,777 tonnes in 1985 (Sauco, 1993). Trade sources also predict a steady increase in demand for mango products not only hot-packed and frozen pulp but also individually quick-frozen slices and pieces, widely used in the beverage and dairy industries (Sauco, 1993).

In general, trade in mango has been limited by its highly perishable nature. The fruit are highly susceptible to physiological disorders and diseases, physical injury, as well defects associated with extreme temperatures. As a result, fresh fruits are difficult to be kept for long-distance transport and subsequently, the cost of fresh mangoes in importing countries is very high due to air transport cost. In order to improve storage potential international and intra-regional trade in mangoes, appropriate postharvest technologies such as control of diseases, insects and physiological disorders, packaging and long-term storage during transport must be applied.

2.2 Maturity Assessment

Maturity is defined by most postharvest technologists as the stage of development which a commodity has reached a sufficient stage of development and its quality will be at least the minimum acceptable to the consumer (Medlicott et al., 1988; Reid, 1992). Maturity is known to influence the chemical composition and respiratory drifts during ripening of several fruits and consequently limits storage life and consumer acceptability (Krishnamurthy and Subramanyam, 1970).

Proper quality, taste and flavour of mango fruits can be assured when fruits are harvested after attaining physiological maturity (Mukherjee, 1972). Mangoes harvested at full maturity, however, do not store well, but if harvested immature fail to ripen properly (Tucker, 1993). Considerable effort has been put into identifying reliable indices of harvest maturity, as this affects subsequent ripening rate, ripe fruit quality, response to various postharvest treatments and processing quality (Lizada, 1993).

According to International Standards (ISFV, 1993), mangoes must be picked at the stage of physiological development that enables them to ensure a continuation of the ripening process until they reach the appropriate degree of ripeness corresponding to the virtual characteristics. However, it is not easy to determine optimum harvest maturity. Many studies have been carried out to identify the correlation between degree of maturity and some physical appearances and chemical components in order to determine the harvest maturity of mangoes. The physical parameters that are relevant to mango maturity include fruit shape, size, peel and flesh colour, shoulder growth, pit around the pedicel, and specific gravity. The chemical parameters include starch, titratable acidity, total soluble solids and sugar content.

2.2.1 Physical Parameters

Specific gravity

Various studies have found that specific gravity appeared to be a good, simple, and non-destructive test that can be employed for judging mango fruit maturity (Mukherjee, 1960 and 1972; Salunkhe and Desai, 1984). Jauhari and Tripathi (1972) found that in the 'Bombay Yellow' mango the correlation of specific gravity and starch content with maturity and quality of fruits was high (r=0.897). They indicated that fruit floated in water in early stages of development (specific gravity < 1) but as maturity approached fruits began to sink in water (specific gravity > 1). However, Thangaraj and Irulappan (1989) reported that changes in specific gravity with time and sinking percentage were markedly different in different cultivars.

Pantastico (1975) recommended that specific gravity was a reliable index in 'Haden' mango. The author showed that 'Haden' mango fruit was found to be immature at specific gravity 1.015 and ready for picking if the value was 1.02 or more.

Shoulder growth

According to Medlicott et al. (1988), mango fruits were categorized into 3 stage of harvest maturity based on their morphological characteristic (Figure 2.1). A 'full-mature' fruit was defined as having outgrown shoulder, formation of a depression at the stem-end, but remaining firm and green. 'Half-mature' fruit had shoulder in line with the stem, while 'immature' fruit had shoulders below the peduncle insertion.

Mangoes harvested from the same orchard throughout the season showed a graduation in physico-chemical characteristics as the season progressed. Full-mature fruit had higher soluble solids and pulp colour scores and lower acidity at each harvest date than half-mature and immature fruit. Soluble solids contents for each maturity stage increased at each harvest date. Acidity at harvest decreased as the season progressed in each maturity stage.

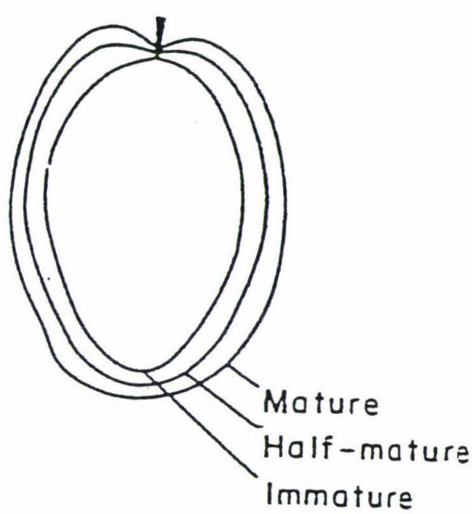

Figure 2.1 Stages of mango fruit maturity based on morphological appearance (From Medlicott et al., 1988).

Colour

Many fruit growers rely on the change of the peel colour and usually harvest fruit when its peel starts changing from green to yellow colour. Pantastico (1975), however, included that this method was not applicable to mango as the fruits harvested at this stage will ripen within a few days and so can not be transported or stored for long periods. The author suggested that it was important to harvest mango a few days before the change in peel colour occurs. Malevski et al. (1977) showed that 'Haden' mangoes at the green maturity stage were classified according to their maximum yellow and red external colour intensity using a Hunter-lab color Difference Meter. Fruits with a more intense initial red or yellow coloration ripened more rapidly than mangoes with less intense coloration. Medlicott et al. (1990) reported that visual peel colour scores during ripening of mango in relation to pulp rupture force and soluble solids content could be used as an acceptable indicator of fruit ripeness.

However, van Lelyveld and Smith (1979) showed that external colour should not be used as the harvest index because the initiation of external colour development of mango fruit like 'Sensation' was found to occur almost simultaneously with the appearance of 'Jelly-seed', the important physiological disorder that often occurs in association with fruit ripening on the tree.

Generally, the colour of mango flesh changes from greenish white to cream or light yellow followed by deep yellow or orange. Mukherjee (1972) showed that though the yellow or orange colour percentage increased in successive picking, the change in colour was not very regular because the flesh colour might have been affected by the position of the fruit on the tree. Fruits situated on the tree away from direct sunlight may not develop proper colour though having specific gravity greater than one. In addition, the method of measuring flesh colour for judging the maturity is destructive and not suitable for practical commercial purposes.

2.2.2 Chemical Parameters

Starch content

It was observed that besides an increase in specific gravity, increase in starch content was closed associated with the maturity of fruit (de Leon and de Lima, 1968; Jauhari and Tripathi, 1972; Krishnamurthy and Subramanyam, 1973; Mukherjee, 1972; Pantastico, 1975; Popenoe et al., 1958). Jauhari and Tripathy (1972); Tandon and Kalra (1983) found a continuous increase in starch content with the commencement of maturity. Maximum starch content was observed at full maturity of the fruit and it declined thereafter.

Starch/acid ratio

Jauhari and Tripathi (1972) found no particular trend in starch/acid ratio in early stages of 'Bombay Yellow' development but at the time of full maturity this ratio was always higher than 3.0. They, therefore, suggested that starch/acid ratio may be useful in judging the correct maturity stage for picking. Lorh and Pantastico (1975) suggested that proper maturity of 'Langra' mangoes is achieved when the starch/acid ratio of the fruit is equal to or higher than 4.0.

From the findings of various studies, it appears that none of the parameters are reliable individually for determining harvest maturity. It would be beneficial to use a combination of several chemical and physical parameters together with considerable experience of industry practitioners. Moreover, these indices vary considerably from cultivar to cultivar, therefore, generalization can not be made for all cultivars. The proper harvest indices should be determined and the recommendations should be set up for each cultivar and when possible for a particular area. For instance, Wang and Shiesh (1990) suggested the following procedure for harvesting mature 'Irwin' mango in Taiwan : First, estimate roughly the days after anthesis to 90 days; Second, select fruits that are still firm, with near round shape and outgrown shoulder. These morphological indices correlated well with the eating quality of the fruit.

The activity of pectinesterase (PE) has been investigated by some authors as an aid to establishing the maturity of fruit (van Lelyleld and Smith, 1979). It was concluded from findings on 'Sensation' mango that PE activity had no apparent connection with fruit maturation in freshly picked fruits, and so cannot be used as a measure of maturity. Mango fruits for nearby markets can be harvested later than fruits requiring several days (e.g. export fruit) in transit before reaching a distance market.

2.3 Harvest Method

Besides the degree of fruit maturity, harvest technique also plays an important role on fruit quality after harvest. Injury on fruit encourages fast ripening, fungal infection and subsequent decay (Mukherjee, 1972). Therefore, careful harvesting is necessary to avoid mechanical damage to the fruit.

There are several common practices in harvesting mangoes:

- Fruit can be picked by hand;
- Fruit on high branches are harvested with a picking pole having a cloth bag (with or without a cutting knife); and
- Mechanical harvesting (vibratory machine).

In using the last method, fruit must be prevented from serious injury caused by dropping on the ground. In order to protect against fruit damage, there is supplied a cushioning materials. Parameswarakumar and Gupta (1991) reported that mechanical shaking-harvesting of mango was technically feasible although there was some damage to tree because of shaking frequency.

The picking pole without knife has a disadvantage as the peduncle will be detached from the fruit causing the mango latex to trickle down the skin which leads to an injury to the peel called 'sap burn' (Holmes et al., 1993). The latex affected portion gradually becomes black when kept in cold storage, imparting a shabby appearance to the fruit.

The recommended methods appear to be hand harvesting or the use of picking pole with a cutting knife. The fruit should be picked with stem (peduncle) slightly above the abscission point. Espino and Javier (1989) recommended 2 cm of the remaining peduncle attached to the fruit (for mangoes grown in the Philippines) and this peduncle can be removed after harvest before placing the fruit with stem-end down on the clean surface for a few hours to allow the latex to drain out completely. However, for 'Kensington Pride' mango in Australia, Holmes et al.(1993) recommended only 20 to 30 minutes. In Florida the latex on fruit, if any, is removed by washing (Malo, 1972).

2.4 Ripening and Senescence

During the ripening process the most profound changes occurring in the fruit are : alteration of pigments, texture and flavour but underlying these are changes in hormonal levels, respiration, and cell organization which bring about a series of biochemical reactions (de Leon and de Lima, 1968).

According to Chaplin (1989), both chemical and sensory properties of mango fruits change as they ripen and these changes vary among cultivars. Generally, ripening of mango fruit is associated with increased colour development, sucrose, glucose, fructuctose, sugar/acid ratio and reduced fruit firmness, alcohol insoluble solids, acidity, tannins, glucose/fructose and citric acid/malic acid ratios.

2.4.1 Respiration

The most significant postharvest change is in the respiration rate. Respiration is the process by which stored organic materials (carbohydrates, proteins, fat) are broken down into simple end products with a release of energy. Oxygen is used in this process and carbon dioxide is produced. Kader (1992) showed that the loss of stored food reserves in the commodity during respiration means (1) the hastening of senescence, (2) reduced food values, (3) loss of flavour quality, and (4) loss of saleable dry weight. The energy released as heat affects postharvest technology considerations such as the estimation of refrigeration and ventilation requirements.

The rate of deterioration of harvested commodities is generally proportional to the respiration rate. Mango is a climacteric fruit (Kays, 1991) and has a high respiration rate, classified as a moderate class with 10-20 mg CO_2/kg-hr at 5°C (Kader, 1992). Therefore, storage life is short.

Krishnamurthy and Subramanyam (1973) reported that the rate of respiration followed a regular pattern and showed a definite climacteric peak during ripening (Figure 2.2). According to these authors the pattern of respiration could be divided into four phases as follows:

- A pre-climacteric phase which lasted until 3 days after harvest when the fruits were green and firm and carbon dioxide was being released at a low rate.
- A climacteric rise which continued up to 6 days after harvest when a sudden spurt in carbon dioxide production was observed but the fruits remained green and firm.
- A climacteric peak which occurred around 9 days after harvest and resulted in a maximum release of carbon dioxide- fruits at this phase tended to change colour, become soft and develop an odour.
- A senescent phase after 10 days when carbon dioxide release declined, an attractive colour developed, the fruit was soft with a pronounced odour and ripening complete. After this stage, senescence of the fruit set in and they became susceptible to infection by micro-organisms.

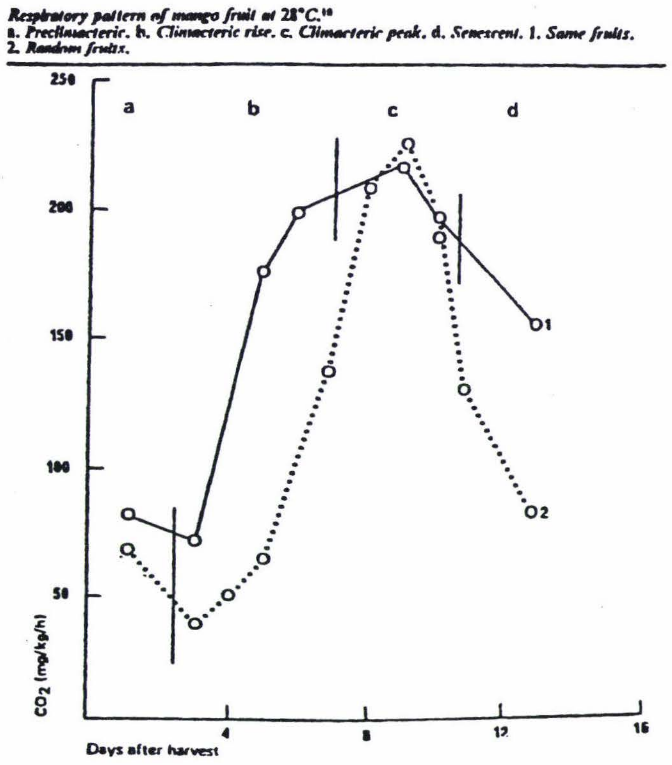

Figure 2.2 Respiratory pattern of mango fruit during ripening.
(From Krishnamurthy and Subramanyam, 1973)

2.4.2 Physical changes

Colour

Unripe mango has a dark green colour. The colour will later change through ripening process, to a perceptible lighter green colour, yellow and yellow-orange colour, respectively (de Leon and de Lima, 1968). Several researchers (Krishnamurthy and Subramanyam, 1973; Medlicott et al. ,1986; and Medlicott et al.,1992) have reported that the loss of green colour and the development of yellow coloration was associated with an almost complete loss of chlorophyll and an increase in carotenoids. Anthocyanin content slightly decreased during ripening. Gomez-Lim (1997) showed that the principal pigments in the fruit are chlorophylls, carotenes, xanthohylls and anthocyanins, which are synthesized via terpenoids or phenylpropanoids (Figure 2.3).

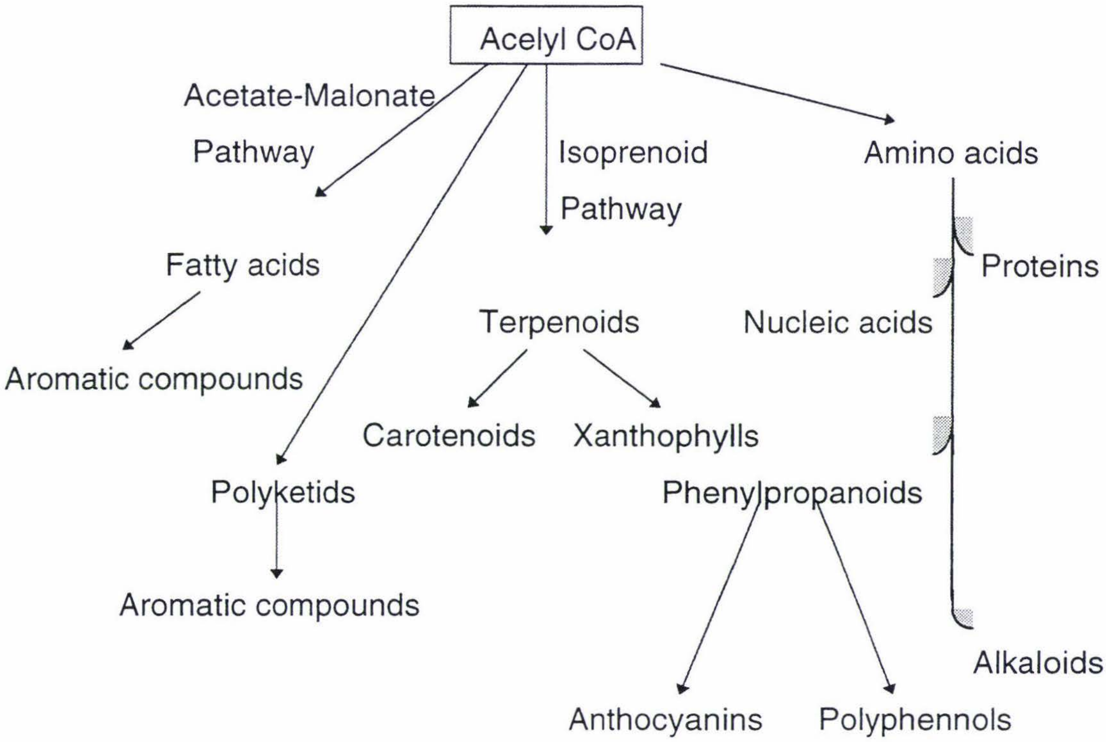

Figure 2.3 Simplified diagram of various metabolic pathways involved in the production of pigments, volatile (aromatic) compounds and polyphenols. The key metabolite is acetyl CoA which is produced by several metabolic pathways (From Gomez-Lim, 1997).

Mattoo et al. (1968) reported that the synthesis of carotenoids in mango involves mevalonic acid and geraniol as precursors. The authors also concluded that phosphatase activity was an important regulatory factor in mango carotennogensis. This process seems to be accompanied both in the peel and the pulp by changes in the ultrastructure of plastids (Parikh and Modi, 1990). Medlicott et al. (1986); Lizada (1993) showed that treatment at high temperature (50-55°C) often results in enhancement of peel colour intensity and a detectable increase in total carotenoids.

Weight loss

Weight loss results from transpiration and respiration; however, weight loss by respiration is small and often negligible. Water loss is the main cause of weight loss. It results not only in direct quantitative losses, but also in losses in appearance (wilting and shrivelling), textural quality (softening, loss of crispness and juiciness) and nutritional quality (Kader, 1992).

Dietz et al. (1989) and Vazquez-Salinas and Lakshminarayana (1985) showed that weight loss of mango increased with length of storage . They reported that the weight loss was influenced by cultivar, storage temperature and culticles and lenticels. Joyce and Patterson (1994) showed that condensate can facilitate invasion of fruit by wound pathogens such as *Rhizopus* spp. (Johnson and Coates, 1993).

2.4.3 Bio-chemical changes

Changes in respiration rate during ripening have been shown to be accompanied by many chemical and biological changes in the fruit. Several reports have reported the pattern of these biochemical changes in mango including sugar, starch, acidity, and enzymes (Abu-Sarra and Abu-Goukh, 1992; Chaimanee, 1992; Gomez-Lim, 1993; Krishnamurthy and Subramanyam, 1973; Lazan et al., 1993; Tucker and Seymour, 1991).

Starch, acidity and sugar contents

Sugars form a high proportion of the soluble solids in ripe mango fruit. After picking, the sugar content increases at the expense of starch already present. At the commencement of ripening, the majority of the sugars are reducing (fructose and glucose) in nature but the ripe fruit contains more non-reducing sugars (in form of sucrose) than reducing sugars (Krishnamurthy and Subramanyam, 1973).

Soule and Harding (1957) studied the changes in physical and chemical constituents of 'Haden' mangoes during ripening at 27°C. They found that rapid changes occurred during the first 3 or 4 days of ripening: total soluble solids increased and starch disappeared. Krishnamurthy and Subramanyam (1973) concluded that during ripening of 'Alphonso' mangoes, there was a breakdown of starch to sugar, and a decrease in acidity (Figure 2.4) to give a desirable acid/ sugar ratio.

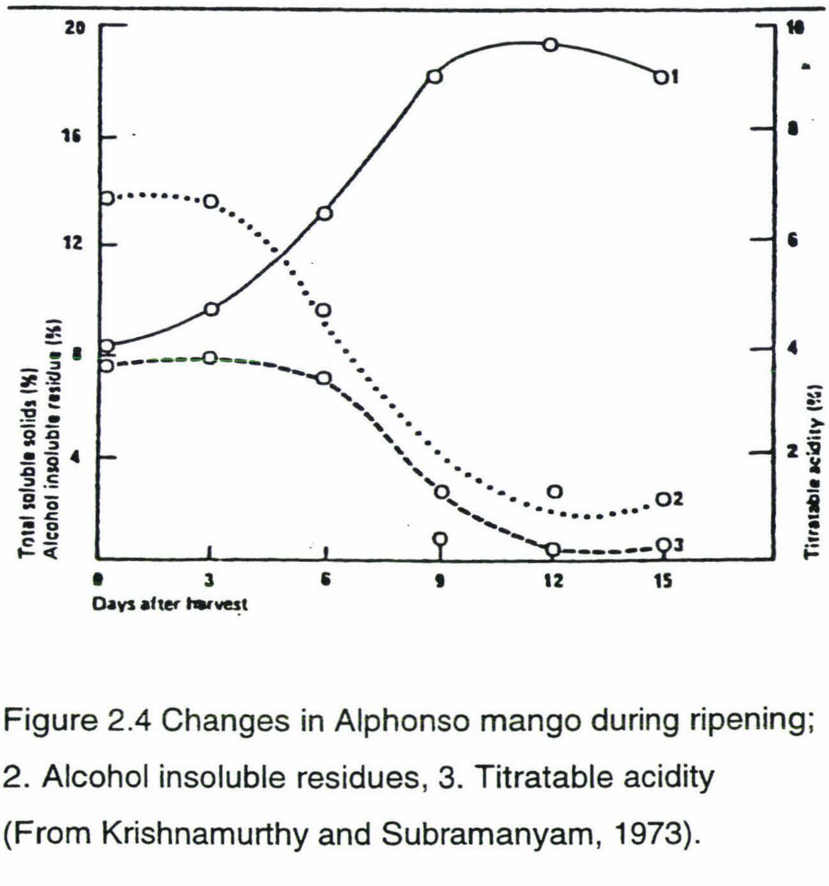

Figure 2.4 Changes in Alphonso mango during ripening; 1. TSS, 2. Alcohol insoluble residues, 3. Titratable acidity (From Krishnamurthy and Subramanyam, 1973).

Protein

Krishnamurthy and Subramanyam (1973) also reported that during ripening the protein content in 'Alphonso' mangoes at 28°C remained more or less unchanged. Kalra and Tandon (1983), however, found that protein contents in 'Dashehari' mangoes were almost doubled during ripening. This increase in protein content suggested that additional enzymes were being synthesized to accelerate changes during ripening. Tucker (1993) supported this idea stating that ripening requires the synthesis of novel proteins and mRNA, apart from new pigments and flavour compounds.

Organic acids

The three major organic acids present in 'Harumanis' mangoes in descending order are succinate, citrate and malate (Lazan et al, 1993). These three acids along with titratable acid level decreased during ripening. The authors also reported that titratable acid and citrate level in inner mesocarp were higher than in outer mesocarp, but declined more rapidly during fruit ripening. The decline in titratable and total acid levels was accompanied by a corresponding increase in pH of the respective tissues.

Amino acids

Krishnamurthy and Subramanyam (1973) showed that aspartic acid and glutamic acid concentrations were high in the early part of the storage period, but they showed a sudden fall at the climacteric peak, γ-aminobutyric acid increased throughout the ripening period.

Cell wall constituents

Changes in the activities of cell wall degrading enzymes such as pectinesterase (PE), polygalacturonase (PG), cellulases and other cell wall hydrolases during mango fruit ripening have been studied by several workers (Abu-Sarra and Abu-Goukh, 1992; Chaimanee, 1992; Gomez-Lim, 1993; Lazan et al., 1993; Tucker and Seymour, 1991). Ripening of the mango fruit is characterized by softening of the flesh. Abu-Sarra and Abu-Goukh (1992) found that fruit firmness of the mango declined during ripening (Figure 2.5). The general observation is that softening during ripening is accompanied by solubilization of pectin involving the action of the enzymes pectinesterase and polygalacturonase. The loss of firmness during ripening of mango fruit is associated with an increase in PE activity, a decrease in PG and in cellulose activity (Abu-Sarra and Abu-Goukh,1992; Roe and Bruemmer, 1981).

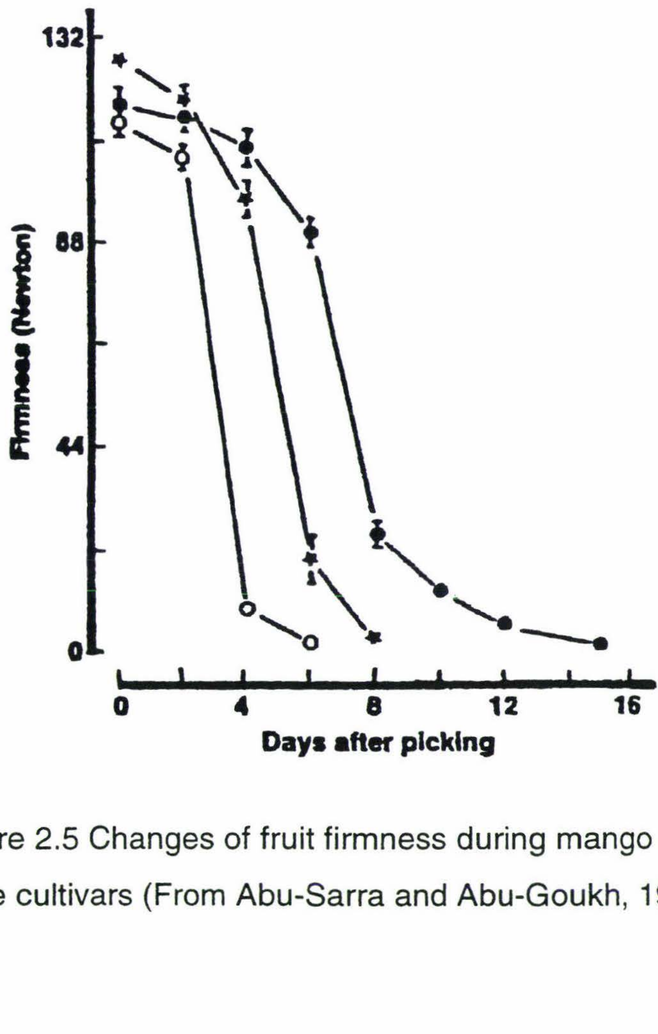

Figure 2.5 Changes of fruit firmness during mango ripening for three cultivars (From Abu-Sarra and Abu-Goukh, 1992)

Vitamins

The concentration of ascorbic acid (vitamin C) decreased during ripening (de Leon and de Lima, 1968); Kalra and Tandon, 1983; Vazquez-Salinas and Lakshminarayana, 1985). Vitamin A values were found to follow the β-carotene trend (Godoy and Rodfiguez-Amaya, 1989) in which concentration increased with ripening.

Tannins

Studies on the nature and chemistry of tannins and related compounds in mango by El Ansari et al. (1971) have revealed the presence of a toxin, gallotannin. Significant amounts occurred in the unripe fruit although only traces were present in the ripe fruit. Kalra and Tandon (1983) also found that tannin levels dropped during ripening.

Volatile substances

Aromatic substances are produced during normal mango ripening. Different mango cultivars can be distinguished on the basis of flavour and aroma (Gomez-Lim, 1997). Ackerman and Torline (1984) identified two novel unsaturated acid esters (2-butenoic and 3-butenoic acid esters), and suggested that these compounds may be responsible for the characteristic aroma of mango.

2.4.4 Indices for ripeness

An increase in sugars, soluble solids content and a sharp drop in tannins and acidity contribute to reduction of astringency and, coupled with aroma biogenesis through ripening process, improves flavour of fruits. However, loss of firmness associated with ripening reduces fruit eating quality and consumer preference. Therefore, to achieve maximum quality, fruit should be consumed at the proper degree of ripeness. Various parameters have been recommended as the indices for ripeness of fruits.

Based on sensory studies, de Leon and de Lima (1968) suggested that starch content appeared to the best index of degree of ripeness of mango fruit. They noted that the starch originally present in the green fruit completely disappeared as the fruit turned yellow. Kalra and Tandon (1983) reported that the optimum stage of 'Dashehari' mangoes to be at 0.3 kPa pressure, 14 or more % SSC, around 5.5% reducing sugars and a peak in amylase activity. Oosthuysee (1991) reported that pulp penetration pressure was the best index for assessing fruit ripeness in 'Sensation' and 'Kent' mangoes compared with degrees of shoulder development, skin and pulp colouration, and SSC.

2.5 Quality Standards of Mangoes

According to Kader (1992), the quality of fresh horticultural commodities is defined, " as a combination of characteristics, attributes and properties for the value for food and enjoyment". Consumers assessed the quality products based on appearance, firmness, flavour and nutritive value. There are several components of these quality attributes:

- Appearance (visual): size, shape, colour, external and internal defects (morphological, physical and mechanical, physiological and pathological).
- Texture: firmness, crispness, juiciness and fibrousness.
- Flavour (taste and smell): sweetness, acidity, bitterness, aroma (volatile compounds), off-flavour and off-odour.
- Nutritive value: carbohydrates, proteins, lipids, vitamins and minerals.
- Safety: toxic substances.

Appearance factors are often the most important quality attributes of commodities. In most fresh products, the rate of deterioration in nutritional quality occurs faster than flavour quality, but the flavour quality is lost faster than textural quality and appearance quality (Kader, 1992).

According to International Standards (ISFV, 1993) mangoes destined for market are classified in three quality classes as follows: "Extra" (superior quality), I (good quality), and II (marketable quality). All three classes require minimum quality attributes such as: intact, firm, fresh appearance, and clean (practically free of nay visible foreign matter). The fruit must be free from black stains or trails which extend under the skin, marked bruising, damage caused by low temperature, pests and damage caused by pests, and free of abnormal external moisture, and any foreign smell and/or taste.

The superior ("Extra") class must have appearance, shape and colouring characteristic of the cultivar and very slight superficial skin defects. The first class (good quality) must have appearance and colouring characteristic of the cultivar and very slight defects in the shape and skin. For the third class (marketable quality) appearance is in keeping with minimum requirements. This class is allowed shape and skin defects. In addition, scattered rusty lenticels, and yellowing of green cultivars due to exposure to direct sunlight (not to exceed 40% of the fruit surface area) are allowed in classes I and II.

2.6 Environmental Factors Influencing Fruit Deterioration

2.6.1 Temperature

Air temperature is the most important variable because it tends to influence the flesh temperature of perishable commodities. Above the optimum temperature, they respire at unacceptable high rates and are more susceptible to ethylene and disease damage (Thompson, 1992). Vazaquez-Salinas and Lakshminaryana (1985) showed the compositional changes in mango fruit during ripening at different storage temperatures. Chemical changes in 'Haden', 'Irwin', 'Keitt' mangoes stored at 16-28°C and 85% relative humidity (RH) were monitored to determine the optimum storage and ripening conditions. Weight loss was slightly higher at 25 and 28°C than at 16-22°C. Breakdown in acidity during ripening occurred at 16°C, particularly in 'Haden' and 'Keitt' mangoes. Vitamin C showed two basic trends : a general decrease as in 'Haden', 'Iwrin', and 'Keitt' or a steady increase as in Kent. Total carotenoids and β-carotenoids were significant higher at 22 - 28°C than at 16 - 20°C. No significant differences were observed with respect to carbohydrate and soluble solids content. However, sucrose increased spectacularly at all temperatures contributing most to the increase in the sweetness. Vazaquez-Salinas and Lakshminarayana (1985), therefore recommended temperatures of 20-22°C and RH 85-90% for storage and ripening of mangoes to obtain sufficiently acceptable quality attributes.

Chilling injury (CI)

Refrigeration is a widely used technology to delay the ripening or postharvest deterioration of fresh horticultural commodities. Hatton et al. (1965) and Thompson (1971) reported that storage temperatures below 13°C were not suitable for mango because of the risk of chilling injury (CI). CI symptoms in mangoes include rind discolouration, pitting, uneven ripening, poor colour and flavour, and increased susceptibility to decay (Kane et al., 1982; Thomas and Oke, 1983).

However, mangoes stored at non-chilling temperatures, i.e. 13°C and above, generally have a storage life of less than 3 weeks due to ripening of the fruits. Thus the potential to export fresh fruit is generally limited to those producing regions from which the shipping time to market does not exceed about 2 weeks. Therefore, the determination of optimum low temperature storage regime for mangoes is an important research problem. Medlicott et al. (1990) found that ripening changes during storage for 21 days were less at 8 and 10°C than at 12°C. However, chilling injury, as indicated by inhibition of ripening, was found in fruit from all harvests, and in early season harvests stored at 10°C. Fruit from mid-and late-season harvests stored better at 10 than at 12°C, with no apparent signs of chilling injury.

Chaplin et al. (1991) studied the development of CI in green 'Kensington' mango fruit held at 1, 5, 10, 15 and 20°C after harvest. Fruits held at 20°C softened and were ripe after 1 week, while fruits held at 10°C and 15°C were in moderate to advanced softening with no visual symptoms of chilling injury. Lowering of storage temperature suppressed flesh colour in ripened fruit and had little apparent influence on peel colour. Only storage at 1°C suppressed total soluble solids in ripened fruit whereas storage at 1, 5 and 10°C lowered the pH and increased titratable acidity in ripened fruit than control fruit or fruit held at 15°C.

Heat injury

Heat treatments are currently used for disease control and disinfestation of mangoes. However, these treatments can result hyperthermal injury (HI). Vapour heat treatment (VHT) of 'Carabao' mangoes at a pulp temperature of 46°C for 10 min induced internal breakdown in the inner mesocarp of the fruit (Esgurra et al., 1990). Injury was characterised by presence of white, starchy lesions.

During studies with mature green 'Kensington' mango by Jacobi and Gowanlock (1995), fruit were submerged in hot water at 46°C until the fruit center reached 45°C and then held for 30 min. The fruits were then allowed to ripen for 7 to 10 days after the hot water treatment, and damage areas of skin and mesocarp tissue appeared. Heat-related injuries included rupturing the patterned culticle and exocarp and exposing the underlying cells and hollow cavities, randomly distributed within the mesocarp beneath the skin. Starch deposits still were present in the mesocarp parenchyma cell. The cell walls of damaged mesocarp parenchyma cells were convoluted and thickened in places. The injury suggested disruption of enzymes involved in carbohydrate metabolism.

2.6.2 Relative Humidity (RH)

The humidity of the air in storage rooms directly affects the keeping quality of the stored products. If it is too low, wilting or shrivelling is likely to occur in most commodities. The rate of water loss from fruit depends upon the vapour pressure deficit between the commodity and the surrounding ambient air, which is influenced by temperature and relative humidity. At a given relative humidity, water loss increased with increase in temperature (Kader, 1992; Thompson, 1992; Wills et al., 1981). Vazaquez-Salinas and Lakshminarayana (1985) recommended that for storage mango at 16-22°C, the relative humidity should be in the range 85-90%.

2.6.3 Ethylene

The effects of ethylene on harvested horticultural commodities can be desirable or undesirable; thus it is of major concern to all produce handlers. Ethylene can be used to promote faster and more uniform ripening of fruits picked at the mature-green stage. On the other hand, exposure to ethylene can be detrimental to the quality of fruit (Kader, 1992). Burg and Burg (1962)and Mattoo and Modi (1969) found that there was a normal pattern of ethylene evolution which coincides with the respiration peak. They showed that ethylene promoted the activities of the enzyme catalase, peroxidase and amylase in slices prepared from pre-climacteric mango.

Meddlicott et al. (1987) reported that in 'Tommy Atkins' mangoes treated with ethylene for 24 hours at 25°C, the pulp rupture force and peel colour increased if treated with more than 0.01 $mL.L^{-1}$ ethylene. Burdon et al. (1996) reported that ethylene production can be inhibited by acetadehyde and ethanol. Ethanol at higher concentrations (0.5 and 1.0 %) increased ethylene production, as did the lower concentrations of acetaldehyde (0.1 and 0.5 %). The ethylene production rate of the 1.0 % acetaldehyde treated discs was not significantly different from the control discs, the increased ethylene production induced by the lower concentrations of acetaldehyde having been eliminated.

2.6.4 Atmospheric composition

For temperate fruit, notably apples and pears, control or modification of storage atmosphere has enabled storage life extension and disease control with minimal reduction in produce quality. However, mangoes have been notoriously difficult to store under controlled atmosphere (CA), with most workers reporting only slight increases in storage life (Spalding and Reeder, 1974; Spalding, 1977). Kader (1994) reviewed controlled atmosphere storage and modified atmosphere (MA) storage of tropical fruits, and noted that that the tolerance of fruit to insecticidal CAs depended upon O_2 and CO_2 levels, fruit resistance to gas diffusion, ethanol accumulation rate and soluble solid content. Preferred conditions for 'Keitt' mangoes have been reported as 5% O_2 and 5% CO_2 and 13°C. At a O_2 concentration of 1%, off flavour development and stem-end rot incidence was a problem (Spalding, 1977). In 'Kensington', Jordan and Smith (1993) reported that fruit firmness showed a clear inverse effect of O_2 concentration and no effect of CO_2 concentration (Figure 2.6). The authors suggested that the range of condition 0.5-2.2 % O_2 and 0-10 % CO_2 (nominal) were a radical last-ditch attempt to achieve a substantial response of 'Kensington' mangoes to CA.

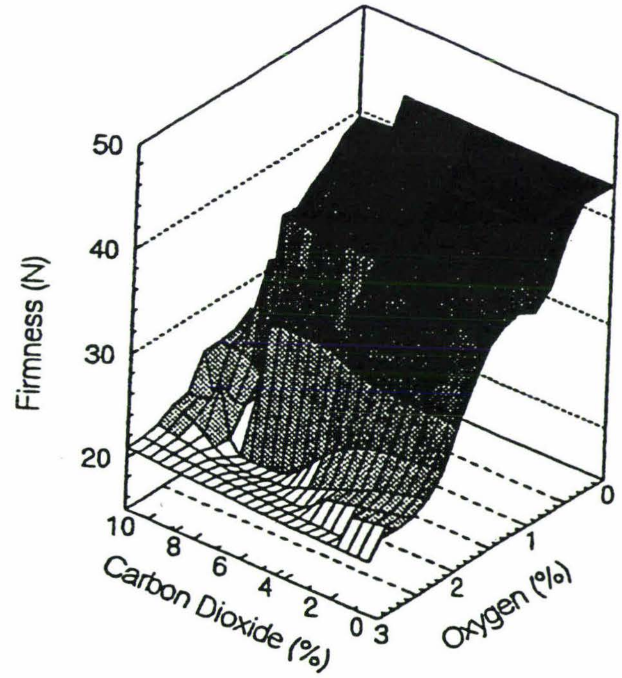

Figure 2.6 The influence of CO_2 and O_2 concentration on the firmness of Kensington mango (From Jordan and Smith, 1993)

Bender et al. (1994) reported that storage of 'Kent' and 'Tommy Atkins' mangoes in elevated CO_2 atmospheres resulted in increased respiration rates, increased ethanol level and reduced ethylene production rates. Reduction of O_2 levels from 20.8% to 3 % the presence of elevated CO_2 had little effect on ethanol and ethylene production. Levels of CO_2 of 45% and higher caused abnormal colour development.

Peacock (1987) reported that controlled atmosphere storage (5% oxygen) at 13°C is commercially feasible for some Australian and Thai cultivars if these are harvested at the right maturity.

The hot water treatment currently used for disinfection against fruit fly can result in quality losses (Jacobi and Wong, 1991; Mitcham and McDonald, 1992). Alternatively, there have been attempts to use either elevated CO_2 or reduce O_2 as quarantine treatments. Bender et al. (1994) reported that storage of mangoes in elevated CO_2 atmospheres resulted in increased respiration rates, increased ethanol levels and reduced ethylene production rates. Reduction of O_2 levels from 20.8 % to 3 % in the presence of elevated CO_2 had little effect on ethanol and ethylene production. Levels of CO_2 of 45% and higher caused abnormal colour development.

2.7 Postharvest Diseases and Disorders

2.7.1 Posthravest diseases

One of the most serious causes of spoilage of mango fruit is incipient fungal infection occurring at different stages of fruit development, the major postharvest fungal diseases being anthracnose, stem-end rot, stem-end cavity and malformation. The causal organism occurs in the fruit which appear normal at the time of harvest but become spoiled during the ripening process.

The unripe mango contains high acid and is not easily attacked by bacteria and fungi; the acid content falls rapidly as the fruit ripens and become more vulnerable to attack (Salunkhe and Desai, 1984). In general, fresh fruit exhibits considerable resistance to potential pathogens during most of their postharvest life. The onset of ripening in fruits, and senescence in all commodities, renders them susceptible to infection by pathogens. Stress, such as mechanical injuries, chilling injury, and sunscald, lower the resistance to pathogens (Kader, 1992).

Anthracnose

Anthracnose is a serious pre-harvest and postharvest disease of mango which usually appears during storage and could completely destroy the fruits within a few days (Mukherjee, 1972). Cappellini et al. (1988) reported that more than 50% of the disease occurrences of mango fruits shipped to New York were anthracnose. Figure 2.7 shows symptom of anthracnose disease of mango reaching the New Zealand market.

Figure 2.7 Symptom of postharvest anthracnose disease of mango.

The anthracnose disease is caused by *Collectrichum gloeosporrioides* (Pelser and Lesar, 1989). For its control a flusizazol application (30 second dip in 1000 ppm flusizazol) preceded by a hot water treatment (5 minute dip in tap water at 55°C) has been recommended (Pelser and Lesar, 1989). The authors also showed that both soft brown rot and anthracnose disease of Kent mango can be controlled by dipping fruit in water at 40°C for 5 minutes, and followed by a 30 second dip in 3000 ppm flusizazol plus 1000 ppm prochlozar (further details in section 2.8).

Stem-end rot

Stem-end rot is another serious disease of mango. It is caused by *Dothiorella dominican, Dothiorella mangiferae, Lasiodiplodia theobromae* (Johnson et al., 1992) and difficult to control (Huang and Liu, 1995). Stem-end rot begins in the flesh and proceeds to outside. Once it appears, the affected fruit becomes unedible.

Johnson et al. (1990) showed that immersion in hot water (52°C for 5 min.) plus benomyl provided good control of stem-end rot on mangoes following inoculation with either *Dothiorell dominican*, or *Lasiodiplodia theobromae* during storage for 14 days at 25-30°C. During long-term storage in controlled atmosphere 5% O_2, 2% CO_2, 13°C for 26 days, followed by air for 11 days at 20°C, hot benomyl followed by prochloraz (Sportak 45 EC, 0.55 $mL.L^{-1}$, 25°C, 30 sec) provided effective control of stem end rot and anthracnose.

2.7.2 Physiological disorders

Mango fruits are susceptible to several physiological disorders which become apparent during ripening and influence fruit quality. Such disorders can be considered as either induced or inherent. Some examples of induced disorders of mangoes are chilling injury after exposure to low temperatures and impaired ripening of fruit after storage in atmospheres containing high levels of CO_2 (Chaplin, 1989). These have been mentioned above. The other important inherent disorders in mango are spongy tissue (or internal flesh breakdown), soft-nose and jelly seed. The study of the inherent disorders of mango is more complicated as their occurrence is often intermittent and thus unpredictable. The predisposing factors responsible for this type of disorder occur presumably during the pre-harvest period (Chaplin, 1989).

Spongy tissue

Spongy tissue is considered as a ripening disorder characterised by fruit with a soft centre, with white corky tissue or internal breakdown. Affected fruits have a high content of unhydrolysed starch (Katrodia, 1989). The peculiarity of this disorder is that the external symptoms of spongy tissue in affected fruits are not apparent either at the time of picking or at the ripe stage. The effected tissue is visible only when the ripe fruit is cut into 2 halves. It is therefore important to have a proper methods for detect the presence of the disorder in susceptible fruit lines. Wainwright and Burbage (1989), and Thomas et al. (1993) used a non-destructive (X-ray) method for detecting spongy tissue.

'Alphonso' mangoes is one of the cultivars that is particularly susceptible to spongy tissue disorder (Katrodia, 1989). The incidence of disorder increased with exposure time and pulp temperature. Katrodia and Sheth (1989) reported that artificial production of 'spongy tissue' can be done by applying proper amount of heat to mature fruits at pre- and postharvest stages. They also observed that the lower part of fruit was significantly more affected than the middle and upper parts and entire fruits. Flesh pulp affected by spongy tissue contained higher acidity and starch content, but lower pH, carotene content, sugars, ascorbic acid, and enzyme activities (amylase and invertase) than non-affected fruits.

The development of spongy tissue is believed to occur due to the heat from the soil (when soil surface temperature reaches 55.8°C due to solar radiation) as convective flux, which reaches the pulp first by way of conduction and then touches the stone, where it gets accumulated raising the fruit pulp temperature to the extent of promoting damage.

Recommendations for controlling spongy tissue are include:

- Breeding for resistance cultivars. (Katodia, 1989).
- Convective heat may be minimised through simple cultural practices such as mulching and sod-culture (Katrodia, 1989).
- Fruits after harvest should not be exposed to high temperature and direct sunlight (Katrodia, 1989).
- The single and double pre-harvest dips of fruit in calcium solution (Gunjate et al., 1979; Wainwright and Burbage, 1989).

However, postharvest dip treatments had no significant effect on reducing the occurrence of spongy tissue and dip treatment with $CaCl_2$ having higher concentrations (2 and 3 %) caused blackening and roughening on the fruit skin (Katrodia, 1989).

Soft-nose

Soft-nose is a physiological disorder in mango often found to occur in the fruit which are allowed to start ripening on the tree (Subramaryam et al., 1971). According to Young and Miner (1961), soft-nose occurs as fruit approaches maturity and evidently always starts on the tree. Unless already initiated at picking, typical and pronounced soft nose does develop after picking. Subramanyam et al. (1971) mentioned that the casual factors for the onset of this internal breakdown are not known and they described physical characters and chemical composition of soft-nose as follows:

- Physical characters: 'Internal breakdown' tissue was generally pale yellow in colour as compared to the surrounding tissue, had a fermented odour and air pockets. The effected tissue was either too soft or hard or leathery, depending on the severity of damage. Occasionally specks adhering to the stone were seen in the initial stages of breakdown. The extent of damage varied from 1-3 cm.

- Chemical compositions: Spoiled tissue showed low pH, higher acidity with low soluble solids and sucrose content as compared to the normal tissue. Total carotenoids and β-carotene content were also lower in the affected tissue but vitamin C appeared to be high in the affected tissue compared to the healthy tissue (Young and Miner, 1961). Burdon et al., 1991 reported that the calcium and magnesium content of the disordered 'Kent' fruit was lower than in the healthy 'Kent' fruit. However, the calcium and magnesium levels of the less susceptible 'Beverly' fruit were as low as in the disordered 'Kent' fruit from the same site.

2.8 Postharvest Handling Systems

Proper postharvest handling is important in order to minimize quality loss of mango fruit after harvest. A good postharvest handling system starts from the orchard after harvest until the produce reaches the consumers. Harvested mangoes should be gently placed away from direct sunlight to reduce moisture loss and heating up of the fruit so as to limit the incidence of postharvest disorders and diseases. After that fruit are transported directly to the nearby local markets or to a pack-house for sorting and grading to desired quality standards.

2.8.1 Pack-house operation

2.8.1.1 Cleaning and disinfection

Mature-green mangoes exude a large amount of latex from the cut stem which can cause injury to the peel called 'sap burn' (Chaplin, 1989; Torchill et al., 1989). Latex can be washed off with water in a tank. The water may also contain fungicide, mainly to control anthracnose (Kader, 1992). Disease control is more effective if the solution is heated (Kader, 1992). This is probably because hot water removes part of the natural waxes on mango fruit surface, thereby facilitating an easier penetration of fungicide into the fruit (Salunkhe and Desai, 1984).

2.8.1.2 Sorting/grading

Mango fruit are passing on moving belts, sorters will remove fruits that are judged immature, overmature, or undersized and those exhibiting limd-rud or other defects. Many physiological disorders in mango can not be detected visually from external appearance. However, recently, Thomas et al.(1993) reported that a non-destructive X-ray can be used to detect 'spongy tissue' disorder in mango fruit.

Sizing of mango fruits is usually still carried out by visually estimates. Use of weight sizers and other mechanical sizers is increasing (Kader, 1992). It is customary in India to size fruit in 3 grades: small (200-270 g), medium (270-320 g), and large (> 320 g) (Salunkhe and Desai, 1984).

2.8.1.3 Quarantine treatments

Postharvest disinfestation procedures, especially for insects like 'fruit flies', are very important due to quarantine requirements imposed by many importing countries (Chaplin, 1989; Espino and Javier, 1989). In the past, chemical fumigation has been the main method and ethylene dibromide (EDB) was widely used. However, several countries have banned the use of EDB because of its risk to human health. There are several disinfestation methods used in mangoes such as hot water treatment, vapour heat treatment, and irradiation.

Hot water treatment

Sharp et al. (1989) reported that heated water was tested as a quarantine to destroy all instars of the Caribbean fruit fly, *Anastrepha suspene*, in mangoes from Florida. Infected 'Tommy Atkins' and 'Keitt' were immersed for 20 - 60 min in water at 46.1 - 46.7°C. Spalding et al. (1988) found that treatment at 46°C for 20 - 60 min reduced anthracnose in 'Keitt' mangoes and stem-end rot in both 'Keitt' and 'Tommy Atkins' mangoes. Treatment at 49°C for 60 min reduced anthracnose in 'Keitt' and stem-end rot in 'Tommy Atkins'. Dipping fruit in hot water at 55°C for 5 min gave good control of stem-end rot of 'Nam Dorkmai' mangoes and without heat injury (Sangchote, 1989). Immersion in hot water (52°C for 5min) plus benomyl has also been found to reduce stem-end rot on mangoes (Johnson et al., 1990).

However, ripening of the treated fruit was accelerated (Salunkhe and Desai, 1984). This was probably be cause some of the natural waxes on the fruit surface were removed by hot water and thus an easier and faster exchange of respiratory gases was facilitated by the increased cell wall permeability. Immature fruit treated with hot water usually did not ripen and became shrivelled. These damaged mangoes had internal vacuous areas. Overripe mangoes treated with hot water occasionally had darkened and depressed lenticels on the peel (Jacobi et al., 1994).

Vapour heat treatment

Vapour heat treatment is the accepted quarantine treatment to control fruit flies for mangoes exported to Japan. Esgurra and Lizada (1990) evaluated the disease control efficacy of high humidity hot-air (HHHA) treatment developed for the disinfestation of 'Carabao' mangoes against orient fruit fly and melon fly. The incidence of anthracnose and stem-end rot was significantly reduced in mangoes heated to a core temperature of 46°C for 10 min, although the onset of decay was not delayed by the treatment.

Coates et al. (1993) also found that HHHA treatment gave good control of anthracnose in Kensington mangoes ripened at 23°C. A combination treatment consisting of HHHA followed by either hot benomyl or unheated prochloraz gave complete control of anthracnose in cool-stored mangoes.

Jacobi and Wong (1992) reported that 'Kensington' mangoes were treated with vapour-heat to a fruit core temperature of 47°C for times ranging from 7.5 to 30 min. They found that the vapour-heat treatment reduced the time for fruit to colour and soften, but did not cause significant internal or external fruit injury.

Irradiation

The preservation of food by irradiation has received considerable attention because the potential of radiation in the postharvest handling of fruit and vegetable lies in the two directions: the disinfestation of produce of fruit flies and other insect pests, and the extension of the shelf life of produce by restricting the growth of wastage organisms and the retardation of aspects of produce metabolism (Wills et al., 1989). The effects of gamma irradiation and disease control treatments on disease severity and postharvest quality of several mangoes cultivars were investigated.

Heather et al. (1991) reported that 'Kensington' mangoes infested with 24-h old eggs or 5-d old larvae of *Bactrocera tryont* (Froggatt) and B. *Jarvisi* (Tryon), were successfully disinfested with gamma radiation at a dose of 74-101 Gy.

Johnson et al. (1990) showed that hot benomyl immediately followed by irradiation provided effective control of anthracnose and stem-end rot of Kensington Pride mango during storage (15 days at 20°C). They also reported that irradiation of 'Kensington Pride' at doses in excess of 600 Gy caused unacceptable surface damage which was particularly severe after long-term controlled atmosphere storage.

2.8.2 Transport

Mango fruit are sensitive to bruising and mechanical injuries. Transport of mangoes either from the orchard to packing-house or from the packing-house to destination markets have to be done appropriately. Transport should be done in the later afternoon or at night when temperature is cool in order to minimize water loss. Avoid overloading and slow down speed when using poor roads.

Exporting mango is usually done by air transport due to its perishability and this causes high prices of mangoes in most importing countries. In order to increase consumption, a reduction in price is to be considered. Sea shipment, though is less expensive and enables transport of larger volumes, but does not guarantee good quality fruit on arrival unless effective treatments to prolong shelf-life is applied.

2.8.3 Packaging

Various containers are used as packaging materials for mangoes. In India, for example, baskets made of bamboo with paddy straw as cushioning material are generally prepared due to their low cost. Other types employed are ventilated wooden boxes of different sizes, fibreboard boxes, and corrugated cardboard cartons of different dimensions, depending upon cultivar and quality of mangoes to be packed. Various types of cushioning materials used such as paddy straw, wood wool, excelsior, vinylite and pliofilm wrapper, paper cuttings and newprint, tissue paper and polyethylene film (Salunkhe and Desai, 1984). International Standards (ISFV, 1993) recommends a standard package for mangoes (Figure 2.8).

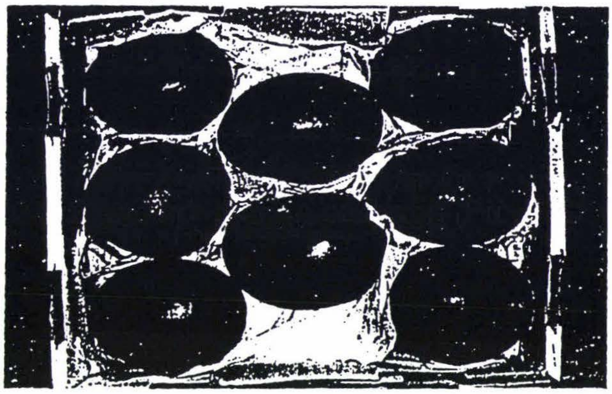

Figure 2.8 Standard mango package (From ISFV, 1993)

2.8.4 Manipulation to prolong shelf-life

Mango is highly perishable and it is a climacteric fruit having rather short shelf-life which rarely exceeds 6 days after harvest at ambient storage temperature of 38 ± 2°C (Kalra and Tandon, 1983). To expand international trade of mangoes, means of prolonging shelf-life and at the same time maintaining the important characteristics like flavour, taste and appearance of the fruit are necessary. Manipulation to prolong shelf-life of mangoes can be done by calcium treatment, pre cooling treatment, cold storage, low pressure storage, controlled or modified atmosphere storage.

2.8.4.1 Postharvest calcium treatment

Postharvest calcium treatment aimed at reducing diseases and disorders also improves postharvest quality of fruit. Tirmazi and Wills (1981) showed that dipping unripe 'Kensington Pride' mangoes in a solution of 4% $CaCl_2$ under reduced pressure (250 mm Hg) and subsequent storage at 25°C resulted in fruit ripening delayed by one week relative to control fruit which ripened after two weeks storage. When the calcium treated fruit ripened, they had a slightly higher level of ascorbic than control fruit but the levels of titratable acid, soluble solids and pH were similar. A taste panel found that the fruit were of good eating quality.

Suntharalingam (1996) showed that fruit of the major commercial cultivar of mango were dipped in cold solutions containing up to 8% calcium chloride and 0.1 %Tween-20 for 2 hours. Fruit were kept under ambient (27 ± 2°C, RH 55 ± 15 %) and cold storage conditions (15 ± 2°C, RH 90 ± 5%). Colour development and textural softening were retarded in treated fruit under both conditions. The rate of weight loss did not depend on the concentration of the dip solutions. Skin injury was observed with the 8% solution. Concentrations of 4 and 6 % extended the shelf life to 9 days under ambient conditions and to 14 days under cold storage, compared with 4 or 7 days for the controls.

Mootoo (1990) reported that calcium chloride treatment of mature green 'Julie' mangoes also retarded ripening of the fruit, as measured by peel colour development and textural softening. The shelf-life of fruit dipped in 8% calcium chloride was 14 days compared with a shelf life of 5 days for untreated fruits.

2.8.4.2 Non-refrigerated Storage

According to International Standards (ISO-6660, 1993) mangoes may be stored in well-ventilated premises at a temperature of 30°C ± 2°C. The relative humidity should be between 60 % and 85 %. The storage life of mangoes is different from cultivar to cultivar (Table 2.1).

2.8.4.3 Precooling

Precooling removes field heat from freshly harvested commodities and prior to loading for transport to the markets and before storage (Johnson et al., 1997; Ryall and Lipton, 1973). Properly carried out, precooling reduces

Table 2.1 Recommended storage life of mangoes without refrigeration (temp. 30°C ± 2°C ; RH: 60 -85%) (From ISO-6660, 1993)

Cultivar	Storage life, days*
Badami	12 to 16
Neelum	8 to 12
Peter (Raspuri)	8 to 12
Malgoa	8 to 12
Totapuri	16 to 20

* Until ripened to an edible state

spoilage and helps retard loss of preharvest freshness and quality. Precooling is first step in good temperature management. Hardenburg et al. (1986) described several methods of precooling : hydrocooling, vacuum cooling, air cooling, and contact icing. Forced-air cooling systems effectively and rapidly remove field heat, and are preferred for bringing fruit to storage temperature. Hydrocooling is also effective, but can increase the risk of infection by wound pathogens such as *Rhizopus* spp. (Johnson et al., 1997).

Puttaraju and Reddy (1997) investigated the effect of different methods of precooling on the quality of 'Mallika' mangoes and they reported that precooling fruits, immediately after harvest, delayed ripening, without any deterioration in fruit quality, however, all the methods used were not equally effective (hydrocooling: 15 and 30 min; running water: 15 and 30 min; roocooling 30 and 60 min; ice cooling: 15 and 30 min; and evaporative cooling). Cooling the fruits under running cold (4-5°C) water for 30 min effectively lowered the fruit temperature by 16°C and significantly retarded the ripening, thereby extending the storage life by 3 to 4 days, while retaining fruit quality. Although ice cooling was the most effective method in reducing the physiological loss of weight (PLW) and maintaining fruit firmness, the sensory quality of these fruits was unacceptable, due to high spoilage.

2.8.4.4 Cold storage

As mentioned earlier, mangoes are susceptible to chilling injury (CI) so cold storage has to be appropriately designed to avoid CI. Storage of immature fruits should be avoided as they are more susceptible to CI (Medlicott, 1990; Thompson, 1971). The optimum temperature for cold storage has to be identified according to cultivars., stage of maturity and ripeness of fruit to be placed in the cold storage. International Standards (ISO-6660,1993) recommended optimum conditions for cold storage of several mango cultivars. (Table 2.2). And after cold storage, fruit should be transferred to 20-25°C to complete ripening and to achieve full potential quality development (Medlicott, 1990).

Low pressure storage of < 100 mm Hg (Salunkhe and Desai, 1984; Ilangatileke and Salokhe, 1989) was reported to be effective in extending the storage life of mangoes. Ilangatileke and Salokhe, 1989 showed that the application of hypobaric storage delayed the ripening of mangoes up to 4 weeks. The authors also reported that storage under a pressure range 100-60 mm Hg at 13°C was found to give the best result. At low pressure storage, mangoes developed excellent colour when ripe both in the pulp and skin, while the total soluble solids did not differ significantly with the control. High relative humidity is required to minimize weight loss during storage.

2.8.4.5 Controlled atmosphere (CA) and Modified atmosphere storage (MA)

Controlled or modified atmosphere is generally used to refer to situations where the gas composition is altered by respiration of stored produce and in CA the gas composition can be controlled more extensively and effectively. The role of atmospheric composition during fruit ripening has been discussed in section 2.6.

Table 2.2 Recommended optimum conditions for cold storage of mangoes (Relative humidity 85-95%) (From ISO - 6660, 1993).

Cultivar	Recommended temperature (°C)	Expected storage life (weeks)
Carabao (Philippines)	9 to 10	2 to 3
Alphonse & Totapuri (Sudan)	> 13	-
All Egyptian cultivars except Company	10	2 to 3
Company (Egypt)	10	4 to 5
Irwin, Tommy Atkins	10	3
Haden, Keitt	13	2 to 3
Keaw Sawoey	10	3
Nang Klarngwun	12	4
Okrong	10	3
Pimsen Mun	9	4
Rad	9	4
Tongdum	9 to 10	4

The application of CA to mango storage has been studied for different cultivars. but there is no recommended atmospheric composition applicable for all cultivars. However, Kader (1992), Salunkhe and Desai (1984) reported that the best results for most cultivars occurred when fruit were stored at 13°C with 5% O_2 and 5% CO_2 up to 20 days. Modified atmosphere can be generated by the fruit itself by surface coating or modified atmosphere packaging (MAP). The final atmospheric composition is not controlled like in CA storage but is dependent on interaction between produce, barrier, and environment. Kader (1994) showed that suitable regimes for MA storage of mango of O_2 3-5% (5-7% for Southeast Asia grown cultivars), CO_2 5-10% and 13°C (10-13°C), with reduced O_2 delaying ripening, and increased CO_2 favouring firmness retation. In general, the atmospheric composition of CA or MA has high CO_2 concentration and low O_2 concentration.

Surface coating

Surface coating such as waxes can be used as a physical barrier around the fruit to reduce air movement across its surface and the atmospheric composition around fruit is then modified. The degree of efficiency depends on the permeability of the surface coatings (Wills et al., 1989).

Many studies indicated that waxing of mangoes reduced rate of weight loss during storage (Parmar and Chundawat, 1989; Shivarana Reddy and Thimma Raju, 1989). Shivarana Reddy and Thimma Raju (1989) showed that fruits treated with 6% wax emulsion recorded the lowest weight loss compared to all other treatments and control at the end of 20 days storage and they had the lowest percentage of spoilage as compared with other treatments.

Modified atmosphere packaging (MAP)

MAP is a common technique to prevent weight loss and extend storage life of perishable products (Ben-Yehoshua et al., 1994). Rodov et al. (1994) showed that sealed-packaging fruits in the plastic film reduce shrivelling, provided better appearance and extended storage life 'Tommy Atkins' and 'Nam Dork Mai' mangoes stored at 13°C (Fig. 2.9).

However, perforated film enables MAP to maintain the advantages of sealed-packaging without the possible anaerobiosis and avoid poor ripening found in unperforated packaged fruits held at ambient temperature (Yantarasri et al., 1995). Yantarasri and his colleagues showed that mangoes in the perforated plastic bags (SM) had lower weight loss and shrivelling compared to nonsealed, had better firmness compared to nonsealed and unperforated (MD) (Fig. 2.11). Mangoes are usually packed in low and high density polyethylene films (Gonzalez et al., 1990).

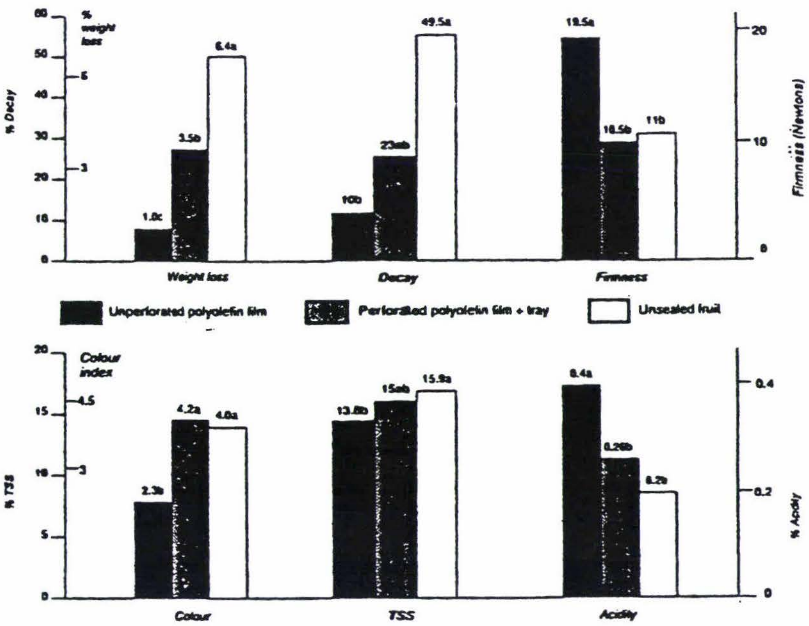

Figure 2.9 Effect of sealed-packaging on keeping qualities of 'Tommy Atkins' mangoes stored for 3 weeks at 14°C and at 17°C (From Rodov et al., 1994).

2.9 Summary and Further Researches

2.9.1 Summary

Mango is a climacteric fruit and therefore is highly perishable. The fruits are also highly susceptible to physiological disorders and diseases, extremes of temperatures and physical injuries. There are many physical, physiological and biochemical changes as well as compositional changes occurring during development, maturation, ripening and senescence of the commodity. The ripening process is influenced by environmental factors such as temperature, humidity, atmospheric composition and ethylene.

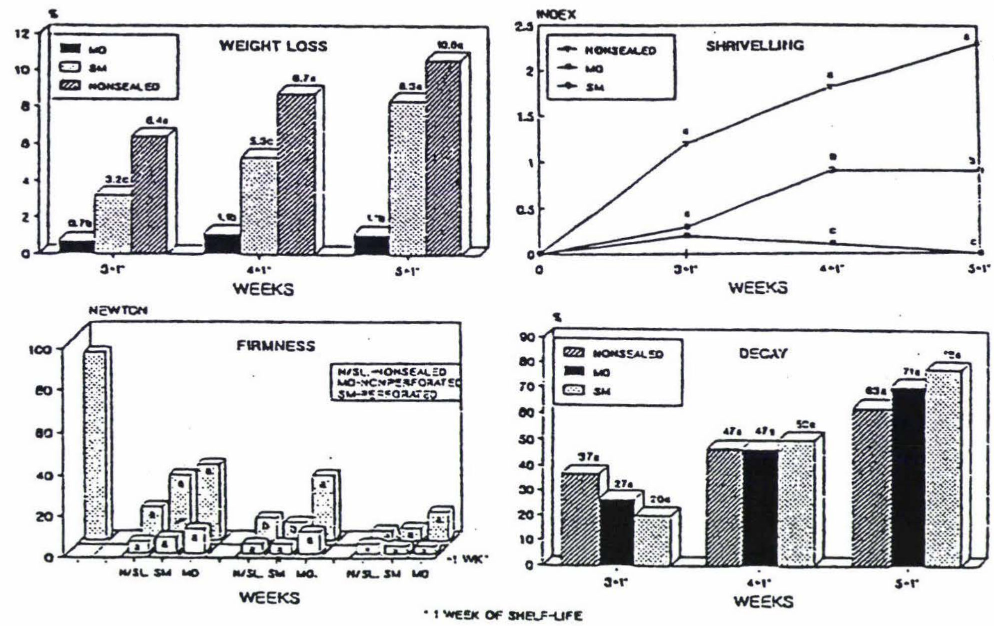

Figure 2.10 Effect of sealing on keeping qualities of 'Keitt' mangoes (Yantarasri et al., 1995)

Determination of maturity index of fruit for harvesting is a complicated process. A single method is often not enough for predicting harvest date of mango; therefore, a combination of methods is usually used.

There are many postharvest physiological disorders and diseases such as chilling injury, heat injury, spongy tissue, soft-nose, anthracnose, stem-end rot etc. which also influence mango quality. To reduce disorders and diseases, postharvest treatments such as hot water treatment, vapour heat treatment, irradiation, or combination with chemicals are used.

Shelf-life of mangoes can be prolonged by calcium dipping, cold storage, and controlled or modified atmosphere storage. Because of chilling injury and storage physiological disorders, for most cultivars of mango fruits, it is recommended that they be stored at 13°C or above for cold storage; for low pressure storage 13°C and pressure from 60 to 100 mm Hg; for controlled or modified atmosphere, 13°C, 5% O_2, and 5% CO_2 is generally recommended.

2.9.2 Further research prospects

Cultivar difference is an important factor affecting the postharvest handling and storage of mango. There have been considerable research on postharvest treatments, cold storage, CA and MA storage of different mango cultivars in various growing regions in the world. However, according the results of my preliminary survey of current practices of 50 growers in Tien Giang Province (major area growing mango) in Vietnam in March 1997, there was very high postharvest losses (about 30%) and a lack of application of postharvest treatments and cold-storage technologies to extend the period of fruit availability during the year. These factors limit the development of an export mango industry and research is therefore urgently needed to determine the appropriate postharvest requirements of the important cultivars grown in Vietnam.

CHAPTER 3

GENERAL MATERIALS AND METHODS

3.1 Introduction

In this chapter, the materials and methods which apply to more than one chapter of the thesis are presented. The others which are specifically relevant to individual chapters are included in those chapters.

3.2 Supply of Fruit

Mature, green 'Buoi' mangoes were carefully harvested by a picking pole having a cloth bag with a cutting knife during the morning hours from 7-year trees in the commercial orchard in Hoa Loc area, Cai Be district, Tien Giang Province, Vietnam. Fruit were packed in the baskets covered by paper (Figure 3.1) and transported to the Postharvest Technology Institute (PHTI) in Hochiminh City by car in 12 hours (ambient temperature 28 - 34°C). In the institute laboratory, fruit samples were examined for the presence of mechanical injuries , pets and diseases and sorted accordingly. Samples to be used for future experiments were immediately selected and put in the cold store. Tests on fresh fruit were carried out within 12 hours of harvest.

Fruit samples were harvested at commercial maturity on 10/3/97, 24/3/97, and 7/4/97 based on uniform peel colour (Malevski et al., 1977) and uniform morphological characteristics such as size and shape (Medlicott et al., 1988).

Figure 3.1 'Buoi' mangoes packaged for transportation.

3.3 Measurement of Postharvest Quality Attributes

3.3.1 Weight loss

Fruit were weighed before and after storage on a Mettler (Toledo PR1203, ± 0.01 g) electronic balance. The weight loss rate was calculated by the following formula:

$$Wr = \frac{Wi - Wa}{Wi}.100 \qquad (3.1)$$

Where: Wr - weight loss rate, %

Wi - initial weight, g

Wa - Weight after removal from cold storage, g.

3.3.2 Skin and pulp colour

Visual skin colour was determined on a scale of 1 - 5 (Medlicott et al., 1988), where 1 = green; 2 = more green than yellow; 3 = equal amounts of and yellow; 4 = more yellow than green; and 5 = yellow. Visual pulp colour was assessed on a scale of 1 - 5 (Medlicott et al., 1988) where 1 = white; 2 = yellow-white; 3 = yellow; 4 = yellow-orange; and 5 = orange.

3.3.3 Fruit firmness

Fruit firmness was measured by using a hand-held Effegi penetrometer (Model FT 327) fitted with 10.9 mm diameter probe. Measurements were taken on one cheek on the equatorial surface of the fruit after removing the skin using a potato peeler. Fruit firmness was recorded as the force (kg) required to penetrate the tissue and converted to Newton (N) by multiplying by the gravitational constant g (9.807 m s^{-2}).

3.3.4 Flesh crushing stress

The Massey Twist Tester was used to measure the crushing stress (σ_{cr}) of fruit fresh (Figure 3.2). Details of the principle and theoretical analysis of this alternative test for the mechanical properties of fruit has been reported by Yuwana (1991) and Studman and Yuwana (1992).

This twist tester measures the moment required to crush fruit cells using a blade and this moment is converted to a crushing stress figure for the tissue by calculation. The principle of the twist tester is showed in Figure 3.3 and for an element of fruit flesh with a radial with *dx* and length *b*, the flesh crushing is obtained as following formula:

$$\sigma_{cr} = \frac{M.\sin\theta}{a^2.b}, \qquad (3.2)$$

Where:

σ_{cr} = flesh crushing stress, Pa

M = the maximum moment produced when the arm is horizontal, N.m

θ = angle of rotation of twist arm at full crushing, m

a = blade radius, m

b = blade with, m

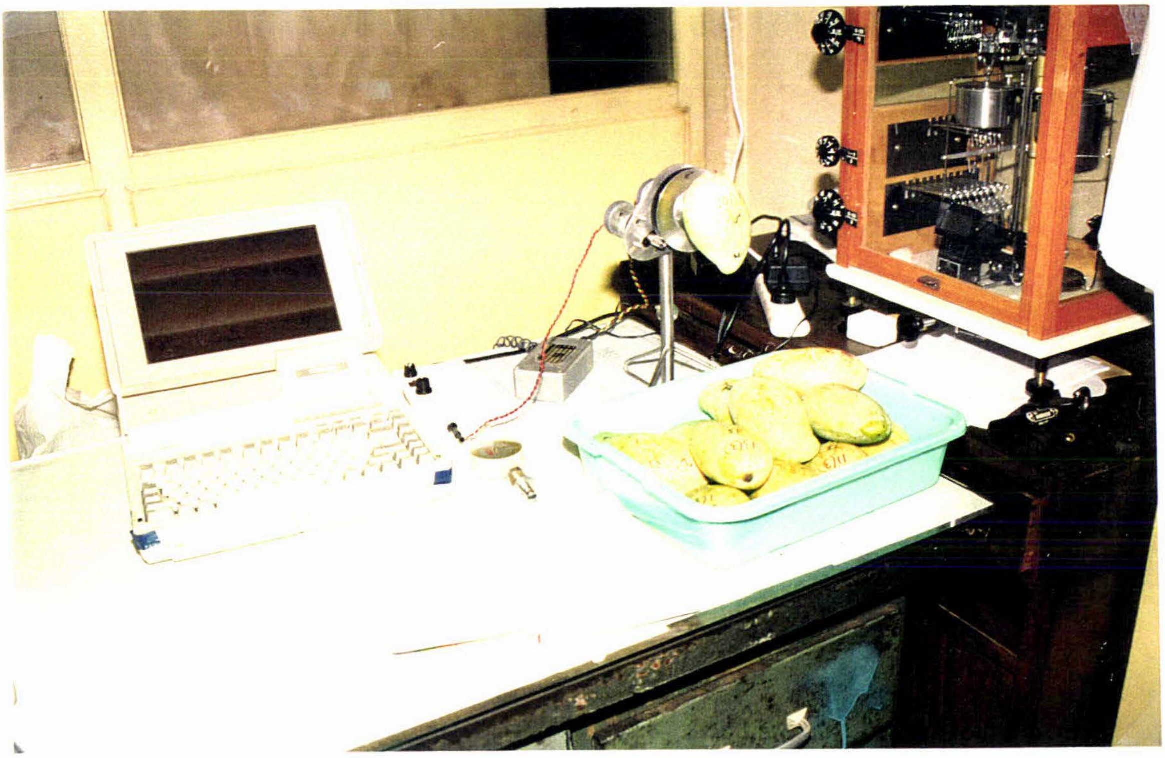

Figure 3.2 Texture measurement of mango fruit by using the Massey Twist Tester.

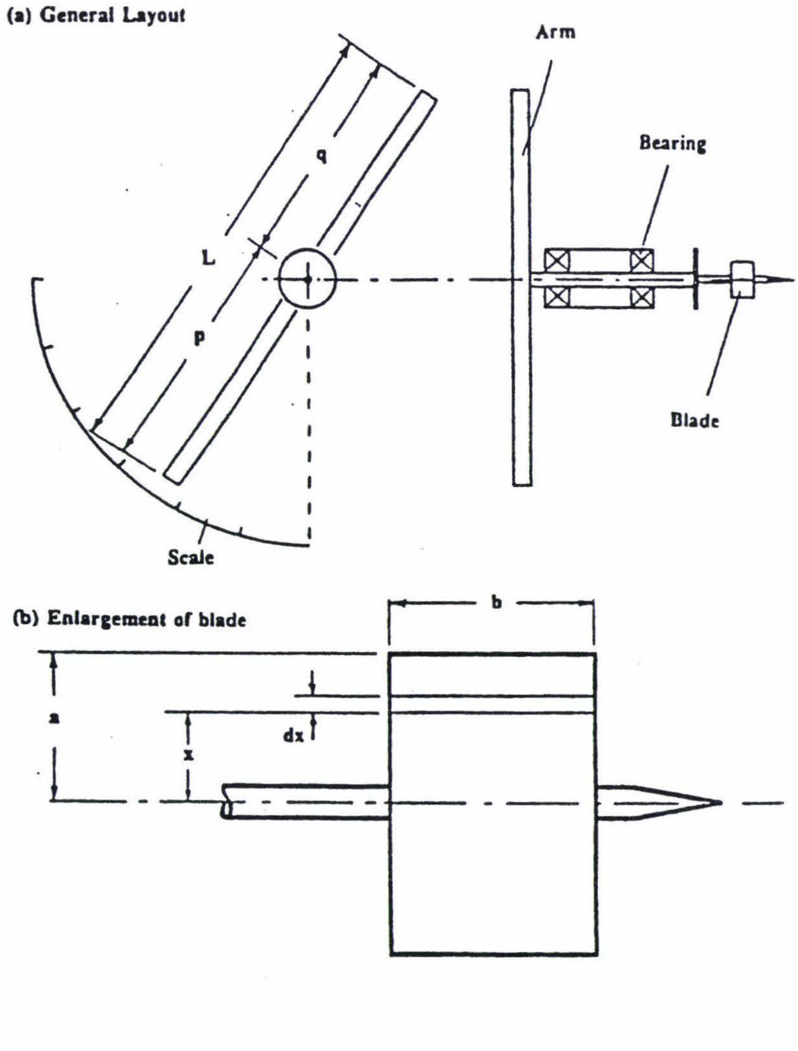

Figure 3.3 Principle of Twist Tester (a) General layout, (b) Enlargement of blade (From Studman and Yuwana, 1992).

The Massey Twist Tester was connected to a portable computer (Toshiba T1600) (Figure 3.2). After every test, the result of maximum crush strength was displayed on the computer screen.

3.3.5 Soluble solids content

The soluble solids of expressed fruit juice (% Brix) was measured using a hand held refractometer (Atago N-20, Brix 0-20%). Before starting each test, the refractometer was zeroed using distilled water. Two measurements were made on the opposite sides of the equatorial surface of each fruit. Each measurement, a sample of the fruit pulp was crushing by crusher (Figure 3.4). After every test, the surface of the refractometer were cleaned using tissue paper.

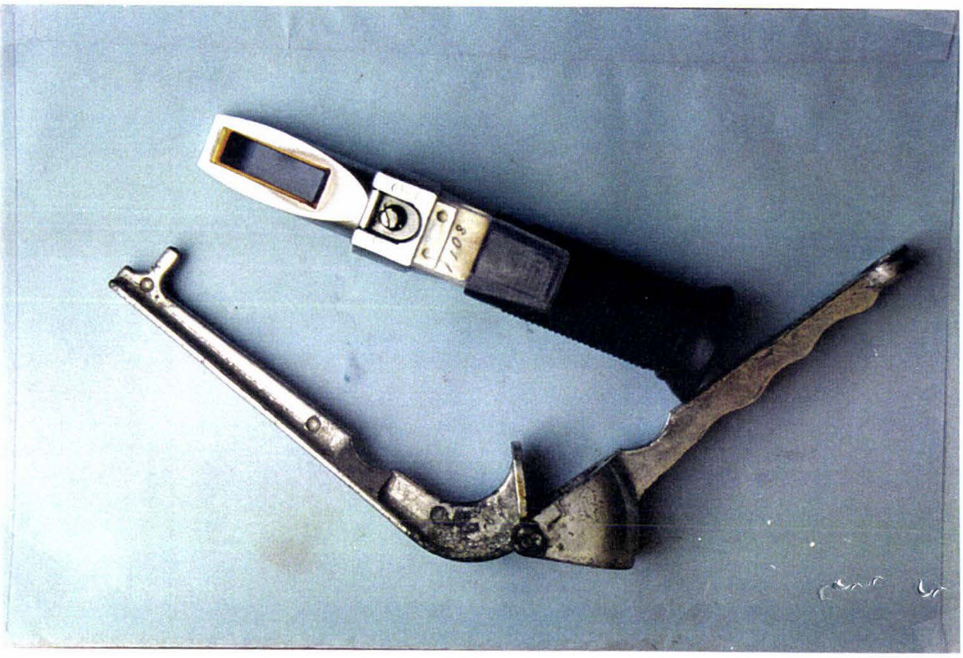

Figure 3.4 A hand refractometer Atago N-20 (above) and fruit tissue crusher (bottom).

3.3.6 Total acidity

Acidity was determined by chemical analysis (So and Thuan, 1991). A sample of 10 g mango pulp was crushed into very small pieces and put into a probe with pure water. After shaking, the pure water was added to be mixture until the level of liquid in the probe was up to 50 ml. After 1 hour, 25 ml was used for further analysis. Five drops of phenolphtalein were put into 25 ml test liquid. Used NaOH 0.1 N dropped into test liquid until the liquid changed to slight pink colour. Recorded the amount of NaOH 0.1 N used. The total acidity was calculated by following formula:

$$TA = \frac{2.k.n}{P}.100, \quad (3.3)$$

Where:

- TA = total acidity, %
- k = coefficient of individual acid (for fresh fruit, coefficient of citric acid k = 0.0064)
- n = amount of NaOH 0.1 N used for the test, ml
- P = weight of the sample, g.

3.3.7 Diseases and disorders

Anthracnose was assessed by a scale of 0 - 4: 0 = non incidence; 1 = slight speckling lesion (< 2 mm); 2 = obvious speckling (1 < lesion <2 mm, unmarketable); 3 = moderate incidence (10-25% blackened surface); and 4 = severed incidence (25-50% blackened surface) (McIntyre et al., 1993). Stem-end rot was based on the greatest browning surface area spread from the stem, rated 0 - 4, where 0 = none; 1 = slight browning around the stem; 2 = browning area less than 5%; 3 = browning area from 5% to 10%; and 4 = browning area greater than 10% of the whole fruit area (Huang and Liu, 1995). The severity of chilling injury in stored fruit was determined by visual rating of the severity of symptoms where 0 = non incidence, 1 = slight incidence (up to 5% surface affected); 2 = moderate incidence (6-25% surface affected); 3 = severed incidence (26-50% surface affected); and 4 = very severe (greater than 50% surface affected) (Chaplin et al., 1991). A scale of 0 - 3 was used to measure the extent of shrivelling (McIntyre et al., 1993), where 0 = no shrivelling; 1 = wrinkles extend to distal region; 2 = wrinkles extend to central region; 3 = wrinkles extend to proximal region.

3.3.8 Eating quality

Eating quality was determined by a taste test and assessed on a scale of 1-9: 1 = very eating quality; and 9 = excellent eating quality.

3.4 Analysis of Data

Experimental data were subjected to analysis of variance (ANOVA) using the Statistical Analysis Systems (SAS) programmes (SAS User' Guide, 1995). Graphs were plotted using Excel (Version 5.0) for Windows. SAS was also used for regression and correlation analyses.

CHAPTER 4

EFFECTS OF HARVEST DATE AND LENGTH OF STORAGE ON QUALITY ATTRIBUTES OF 'BUOI' MANGOES

4.1 Introduction

One of the major problems currently restricting international trade in mangoes is the wide range of physiological maturities within commercial consignments. Maturity indices are important criteria for deciding when to harvest so as to provide some flexibility in marketing and to ensure the attainment of acceptable eating quality (Medlicott et al., 1988). The methods of determining mango maturity have already fully discussed in Chapter 2. Mangoes harvested at full maturity do not store well for long periods of time. Therefore mangoes intended for long-term storage must be harvested at 'commercial maturity' instead of physiological maturity (Kader, 1992). Fruit harvested at commercial maturity are usually less mature than those harvested for immediate consumption (Kupferman, 1989).

Medlicott et al. (1988) reported that the maturity at harvest of 'Tommy Atkins' mango affected the development of fruit quality when ripened at 25°C. Fruits harvested at the mature and half-mature stages developed good quality characteristics, but immature fruits showed only limited changes during ripening. Storage potential was found to decrease with progressive harvests throughout the season (Medlicott et al., 1990). The authors showed that storage of mature 'Keitt' mangoes for 21 days at 12°C restricted ripening in the first harvest of the season, as indicated by changes in texture, acidity, and peel and pulp colour. When harvested 3 weeks later, fruit underwent substantial softening, with increases in SSC and peel colour during storage. Chilling injury was found in early season harvests stored at 10°C, while there was no evidence of chilling injury in fruit from mid- and late-season harvests stored at 10°C. Seymour et al. (1990) also reported that 'Kent' mango fruit from later harvests ripened more quickly in store, particularly with respect to changes in peel and pulp colour. In conclusion, the previous works (Medlicott et al., 1988; Medlicott et al., 1990; Seymour et al., 1990) indicated that the response to low-temperature storage depends not only on cultivar but also on fruit maturity at harvest, and the time of harvest during the season.

In Vietnam 'Buoi' mangoes are usually harvested over a period of about 1 month, but the effects on quality changes during storage are not known. The objective of the study reported in this chapter was evaluate the effect of harvest date on postharvest quality attributes of "Buoi' mango during storage at 12°C.

4.2 Experimental Design

Mature, green 'Buoi' mangoes were harvested at three different times (14 days between two harvests) in Tien Giang Province, Vietnam and transferred to laboratory in Hochiminh City. Fruit for testing were selected on the basis of freedom from mechanical damage, pests, and diseases.

Fruit were harvested on three dates, representing early (10/3/1997), mid (24/3/1997), and late harvest (7/4/1997), based on surface colour and uniform size (see Chapter 3). On each date, a sample of 120 fruits were randomly selected and stored at 12 ± 1°C (RH 85-90%). Twenty fresh fruit samples were assessed for quality attributes such as fruit firmness, crushing stress, skin and pulp colour, SSC, total acidity, and eating quality. At 5-day intervals, a sub-sample of 20 fruits were randomly removal from cold storage and weighed for calculating weight loss rate. After that ten fruit were assessed fruit firmness, crushing stress, skin and pulp colour, SSC, acidity, chilling injury and eating quality. Another sub-sample of ten fruits were transferred to room temperature (25°C, RH 80-85%) in laboratory room for ripening and assessed SSC, acidity, chilling injury and eating quality after 4 days.

4.3 Data Analysis

Data on weight loss rate, fruit firmness, crushing stress, skin and pulp colour, soluble solids content, acidity, and eating quality were subjected to analysis of variance, and the means were compared using least significant difference (SAS, 1995).

4.4 Results

4.4.1 Effects of harvest date and storage duration on fruit quality

Weight loss

In all three harvests, increasing storage time led to a significant ($P < 0.05$) increase in weight loss (Figure 4.1). After 25 days storage at 12°C, the weight loss rate of 'Buoi' mangoes at three different harvests reached to 9.45, 8.89 and 8.72 respectively for early, mid and late harvested fruit. The weight loss rate of early harvested fruit was significantly ($P < 0.05$) higher than fruit harvested in the mid- and late season, but there was no significant difference between mid - and late harvested fruit.

Peel and pulp colour

Peel and pulp yellowiness of mango fruit increased during storage time (Figures 4.2 and 4.3). There was no significant ($P < 0.05$) differences in peel and pulp colour between fruit in three harvests. The colour indices of peel and pulp changed up to around 3.7 in three harvests after 25 days of storage.

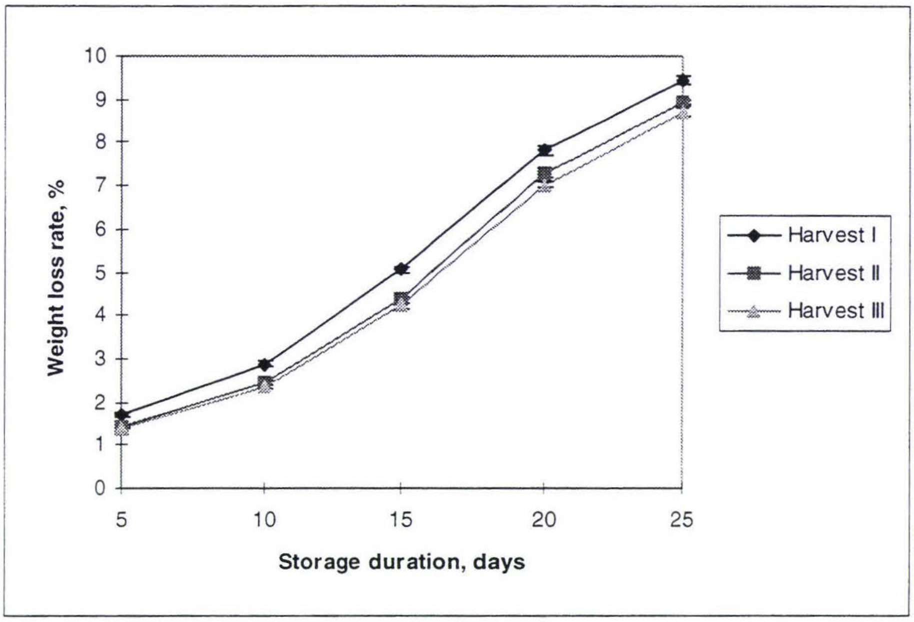

Figure 4.1 Weight loss rate of 'Buoi' mangoes during storage at 12°C (RH 85-90%).

Texture

Flesh firmness and crushing stress significantly (P < 0.05) declined with increase storage time; however, there was no significant difference between fruit stored for 20 and for 25 days (Figure 4.4 and 4.5). Up to 10 days storage, firmness and crushing stress were affected by harvest date. The values of firmness and crushing stress of early harvested fruit was significantly (P < 0.05) higher than those in the mid- and late harvested fruit up to 10 days storage, but after that this difference disappeared .

Soluble solids content

Soluble solids content significantly (P < 0.05) increased up to 20 days storage, but after that declined (Figure 4.6). The highest values of SSC

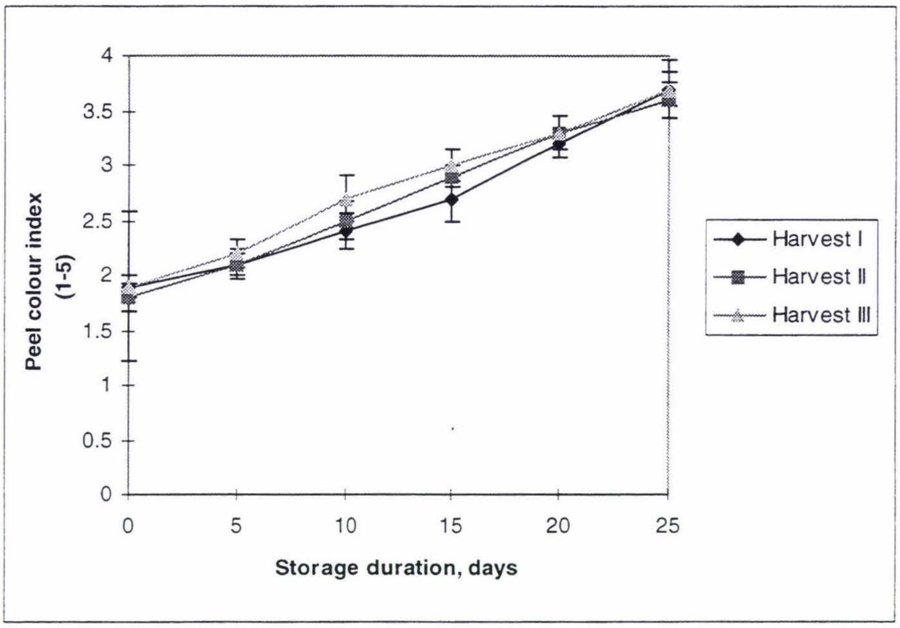

Figure 4.2 Changes in peel colour of 'Buoi' mangoes during storage at 12°C (RH 85-90%).

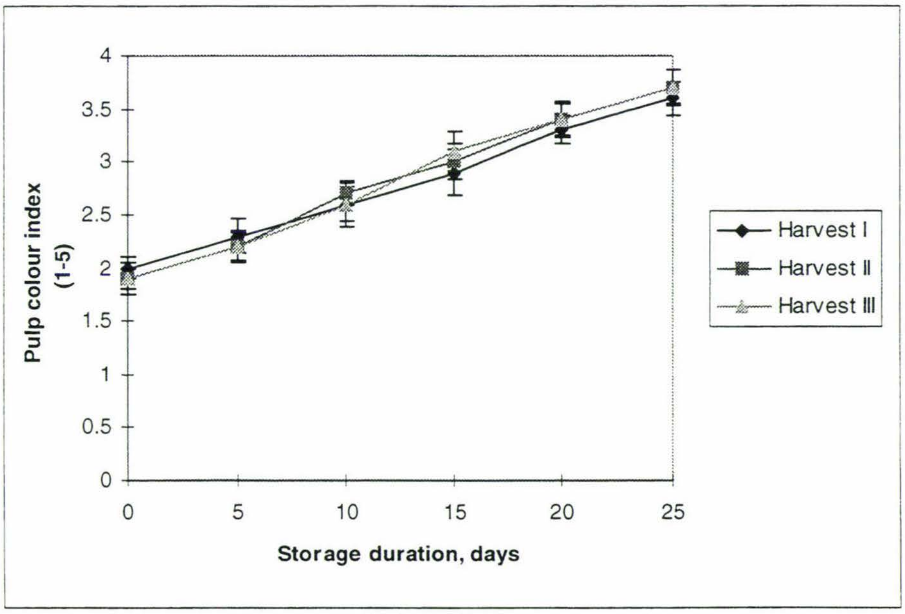

Figure 4.3 Changes in pulp colour of 'Buoi' mangoes during storage at 12°C (RH 85-90%).

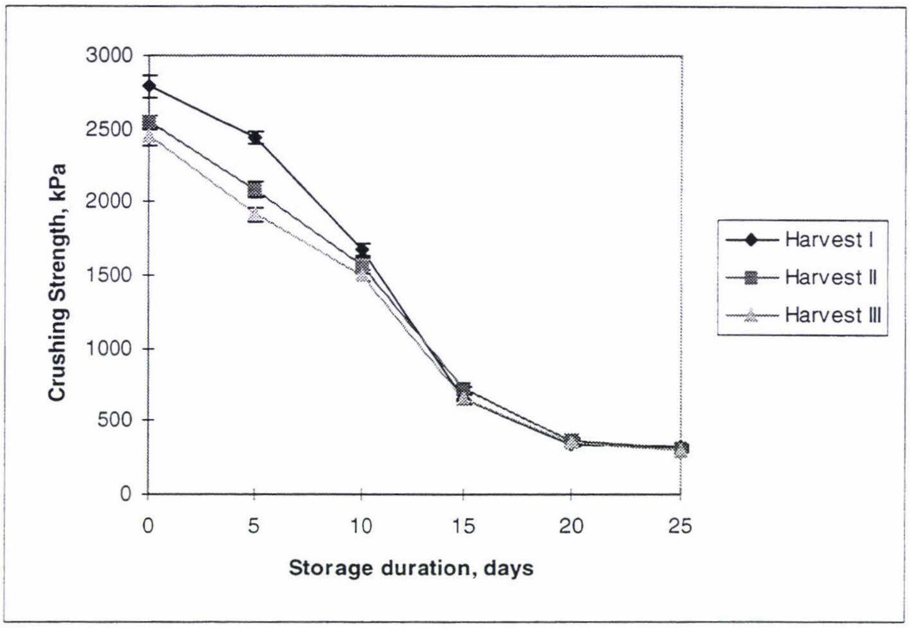

Figure 4.4 Crushing stress of 'Buoi' mangoes during storage at 12°C (RH 85-90).

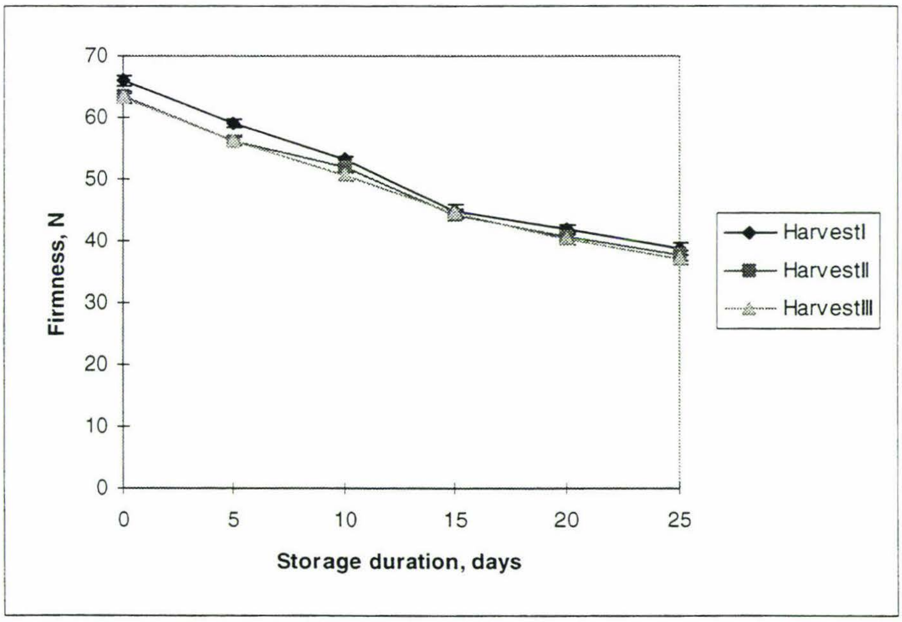

Figure 4.5 Changes in firmness of 'Buoi' mangoes during storage at 12°C (RH 85-90%).

were 12.20, 12.32 and 12.31% for early, mid and late harvested fruit. Up to 10 days storage, early harvested fruit were significantly ($P < 0.05$) lower in SSC compared to the mid- and late harvested fruit, however, after that there was no differences.

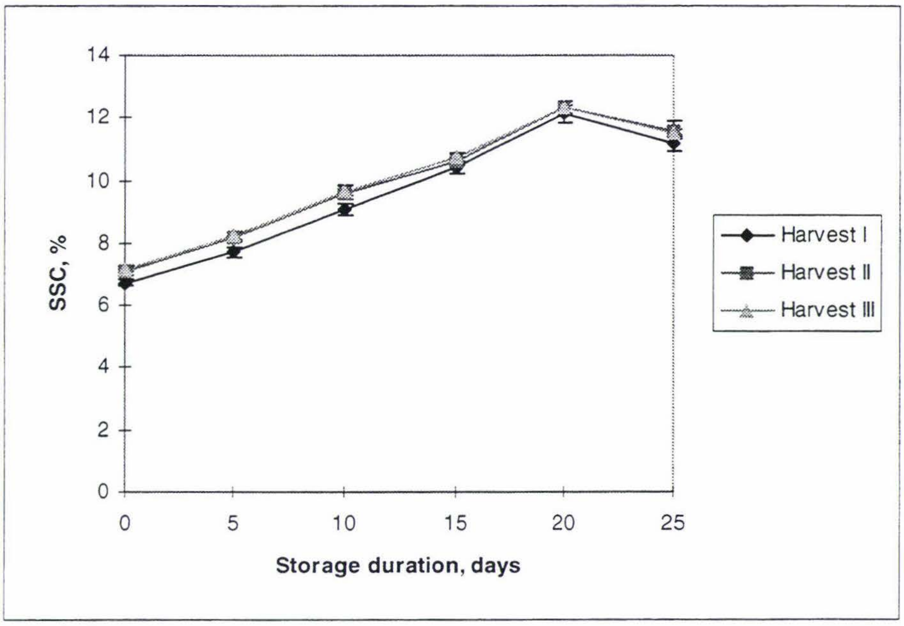

Figure 4.6 Changes in soluble solids content of 'Buoi' mangoes during storage at 12°C (RH 85-90%).

Total acidity

Opposite with SSC, total acidity content significantly ($P < 0.05$) decreased during storage time (Figure 4.7). The harvest date did not significantly ($P < 0.05$) influence the total acidity in the fruit (Appendix 2). In all three harvests during storage fruit reduced total acidity from about 1.3% to about 0.55%.

Chilling injury

Up to 20 days storage, there was only a trace of chilling injury in fruit at the first and second harvest, but after 25 days fruit in all three harvests were severed chilling injury (Figure 4.8). Chilling injury incidence was depended on the harvest date. This incidence in early harvested fruit was significantly (P < 0.05) higher than in mid and late harvested fruit.

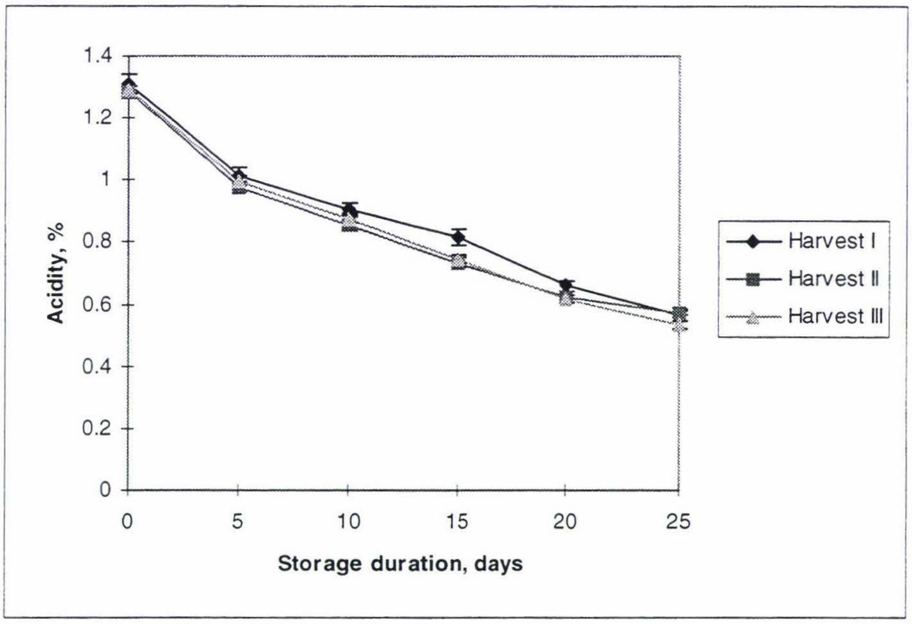

Figure 4.7 Total acidity content of 'Buoi' mangoes during storage at 12°C (RH 85-90%).

Eating quality

The changes in fruit eating quality during storage is shown in Figure 4.9. Eating quality significantly (P < 0.05) increased with increase storage time up to 20 days, but decreased after that. Harvest date did not significantly affect fruit eating quality. The values of maximum eating quality indices for all three harvests were the same, 7.4 .

Data on postharvest quality attributes of 'Buoi' mangoes stored at 12°C (RH 85-90%) in three harvest dates are presented in Appendix 1. Using SAS programme, means and results of ANOVA for the effects of storage temperature and harvest date on fruit quality attributes are shown in Appendix 2.

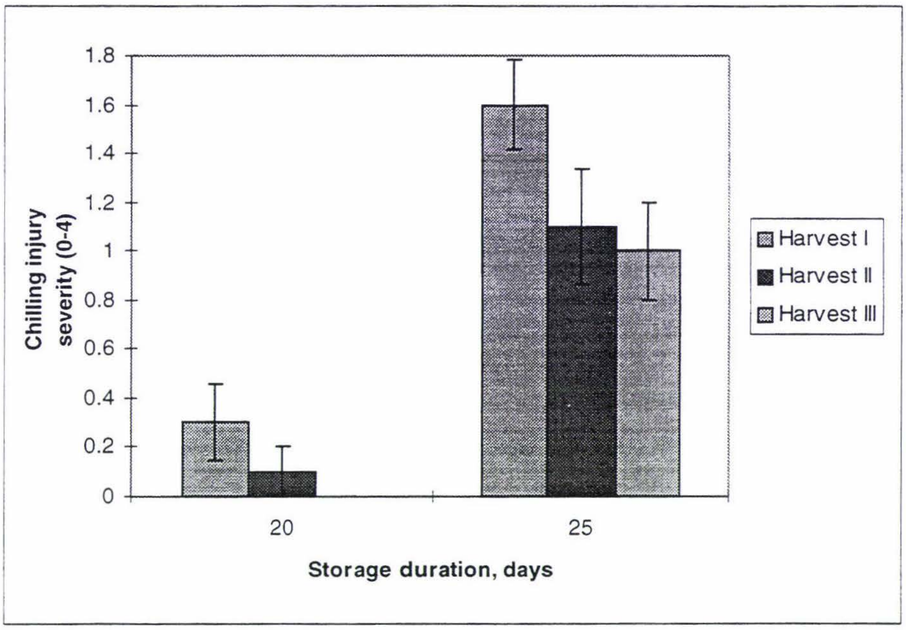

Figure 4.8 Incidence of chilling injury in 'Buoi' mangoes during storage at 12°C (RH 85-90%).

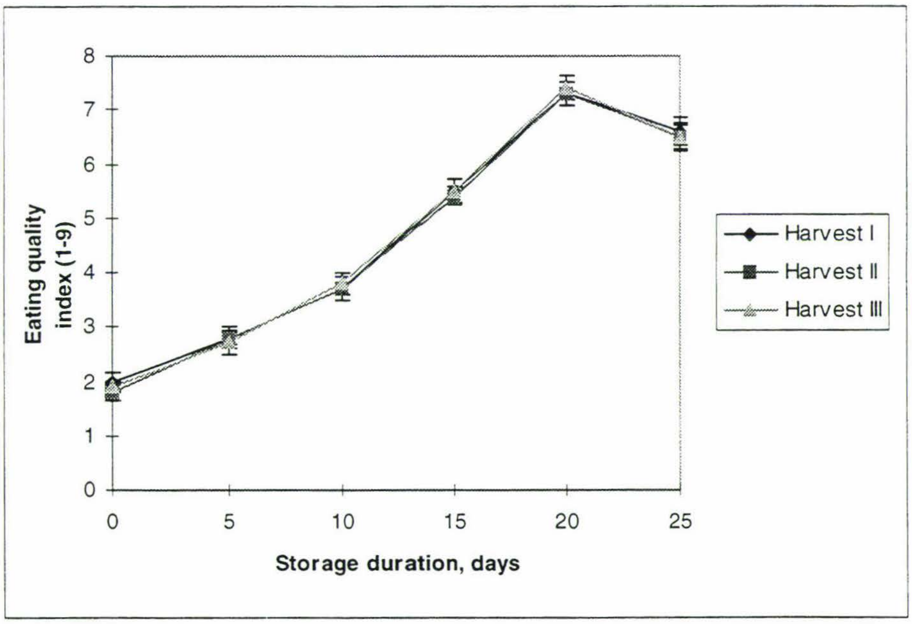

Figure 4.9 Changes in eating of 'Buoi' mangoes after storage at 12°C (RH 85-90%).

4.4.2 Effects of harvest date and storage duration on fruit ripening

The relationships between harvest date and postharvest quality attributes of 'Buoi' mango fruit after ripening are shown in Figure 4.10 to 4.13. In all three harvests, soluble solids content slightly increased up to 20 days storage, but after that decreased (Figure 4.10). After 20 days storage SSC of fruit reached to maximum values. On the other hand, total acidity slightly reduced during storage (Figure 4.11). After 20 days storage and ripening there was a slight incidence of CI, which became serious after 25 days (Figure 4.12). Maximum fruit eating quality occurred between 15 20 days of storage (Figure 4.13).

There were no significant differences ($P < 0.05$) in SSC, total acidity and eating quality between fruit harvested in different dates. However, the harvest date did influence chilling injury. Chilling injury of early harvested fruit was significantly ($P < 0.05$) higher than fruit harvested in the mid and late season, but there was no significant difference between mid - and late harvested fruit.

Comparision of cool-stored fruit abd fruit ripened at 25°C for 4 days showed that both ripening increased SSC (Figure 4.6 and 4.10) and improved fruit eating quality (Figure 4.9 and 4.13), especially during 5 - 15 days storage. Total acidity (Figure 4.7 and 4.11) and incidence of chilling injury (Figure 4.8 and 4.12) were also higher in ripened fruit.

Data on postharvest quality attributes of 'Buoi' mangoes stored at 12°C (RH 85-90%) and 4 days ripening at 25°C for three harvest dates are presented in Appendix 1. The means and results of ANOVA for the effects of storage temperature and harvest date on fruit quality attributes are shown in Appendix 2.

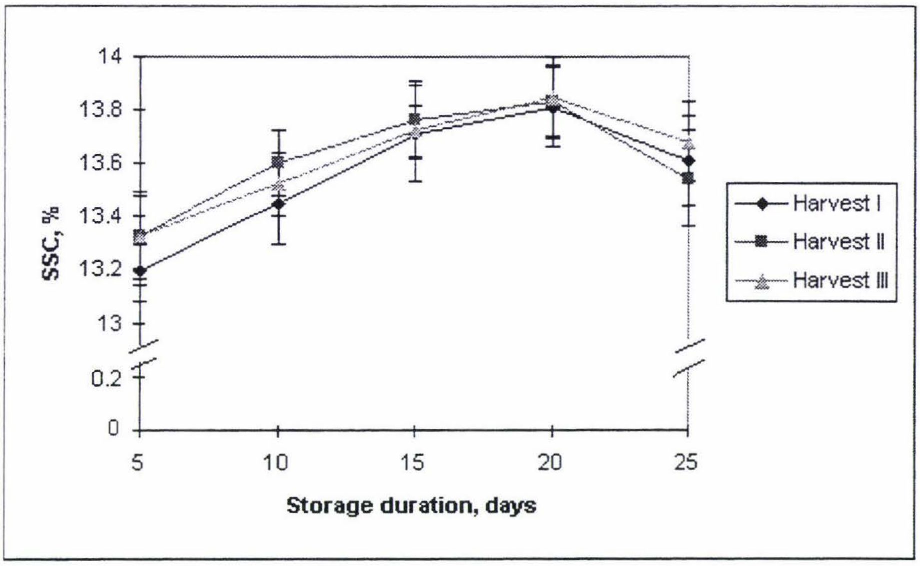

Figure 4.10 SSC of 'Buoi' mangoes after removal from cold storage at 12°C (RH 85-90%) and ripening at 25°C for 4 days.

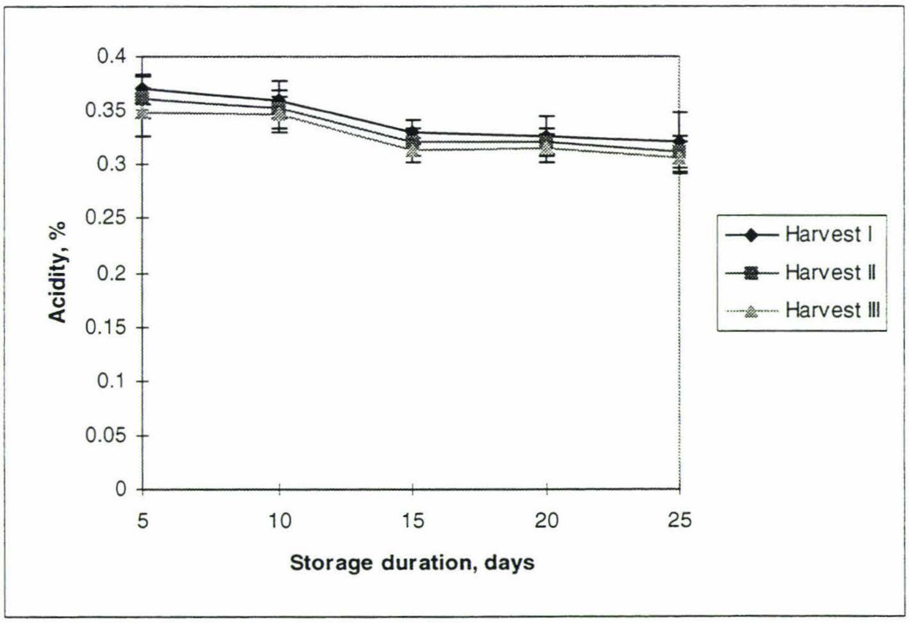

Figure 4.11 Total acidity content of 'Buoi' mangoes removal from cold storage at 12°C (RH 85-90%) and ripening at 25°C for 4 days.

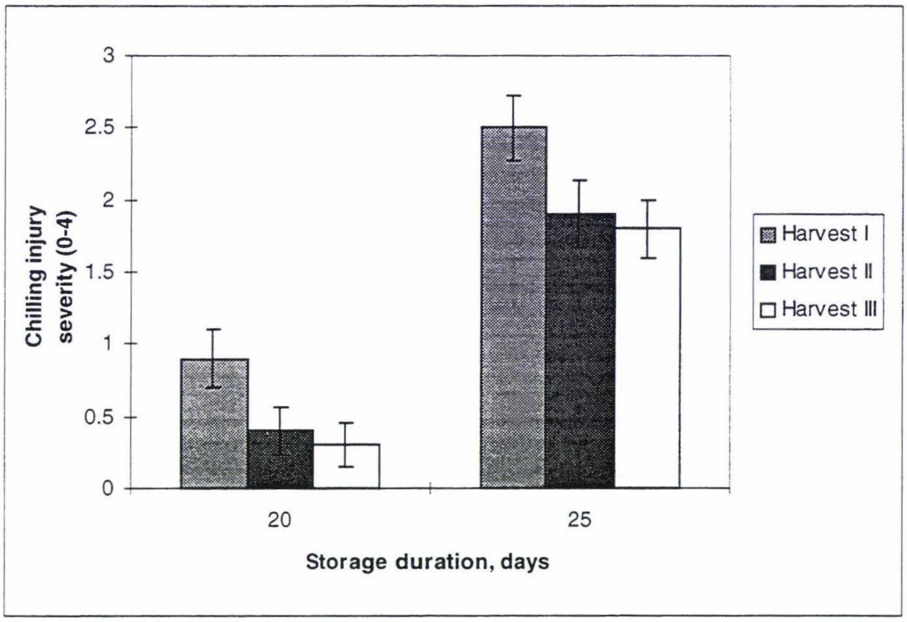

Figure 4.12 Incidence of chilling injury of 'Buoi' mangoes removal from cold storage at 12°C (RH 85-90%) and ripening at 25°C for 4 days.

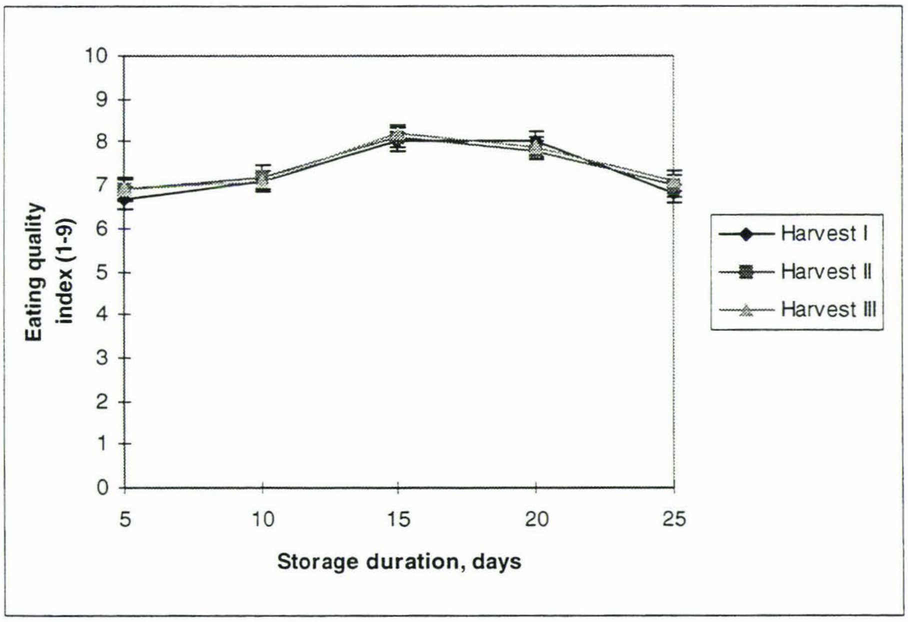

Figure 4.13 Eating quality of 'Buoi' mangoes removal from cold storage at 12°C (RH 85-90%) and ripening at 25°C for 4 days.

4.5 Discussion

The results presented above show that postharvest quality attributes of 'Buoi' mangoes changed significantly during a period of 25 days storage at 12°C. Weight loss which causes desiccation and shrivelling of the fruit increased with increase storage duration (Figure 4.1). This result is similar to the result was reported by Krishnamurthy and Subramanyam (1973) on 'Alphonso' mangoes.

Peel colour of fruit is an important characteristic which is often used as one of the major criteria to determine whether a fruit is ripe or unripe. During storage there was a significant increase in skin yellowiness of 'Buoi' mangoes (Figure 4.2). Medlicott et al. (1986) investigated of 'Tommy Atkins' mangoes and reported the similar result. The authors indicated that the loss of green colour and the development of yellow colouration was associated with an almost complete loss of chlorophyll and an increase in caroteinoids. Similar to the peel colour, the pulp colour of 'Buoi' mangoes significantly changed from white colour to yellow-orange colour (Figure 4.3) . Cua (1989) and Medlicott (1985) also showed similar results in 'Carabao' and 'Tommy Atkins' mangoes and they explained that related to increasing pulp caroteinoids during ripening.

Fruit texture (firmness and crushing stress) declined with increase the length of storage (Figure 4.4 and 4.5). Softening in mangoes is accompanied by an increase in water-soluble, ethanol-insoluble pectins which led Lazan et al. (1986) to conclude that polygalacturonase (PG) might be one of the enzymes involved in mango softening. Medlicott et al. (1985) also observed that PG activity was correlated with textual changes in 'Kent' mangoes ripened at 21°C and 26°C.

The results of compositional changes (soluble solids content and total acidity) in 'Buoi' mangoes during storage (Figure 4.6 and 4.7) were similar to the results reported by O'Hare (1995) on 'Kensington' mangoes. The author also showed that SSC increased to maximum and after that declined and acidity declined with increase storage duration. However, the value of SSC in 'Buoi' was lower and the value of acidity was higher than those in 'Kensington' mangoes.

Figure 4.8 shows that 'Buoi' mangoes stored at 12°C were suffered serious chilling injury after 25 days storage, while only appeared a trace after 20 days. It means that fruit stored longer in cold storage are more susceptible to chilling injury. Chaplin et al. (1991) and Veloz et al. (1977) also reported similar results on 'Kensington' and 'Kent' mangoes.

The results also show that some postharvest quality attributes of 'Buoi' mangoes following storage at 12°C such as weight loss , texture (in first ten days of storage) and chilling injury were significantly ($P < 0.05$) affected by harvest dates. However, harvest date did not significantly affect peel and pulp colour, soluble solids content, acidity and eating quality .

The fruit harvested at early season lost more weight compared with mid- and late harvested fruit. This result can be explained because harvest dates maybe correlated with stages of maturity. When fruit were picked, the morphological characteristics (peel colour and shape) of fruit were used for maturity assessment. However, despite the fact that fruit picked at different harvests were similar in colour and shape, the early harvested fruit were still in immature stage while in the mid- and late harvested fruit they already in half mature or mature stage. Generally, during storage the weight loss rate in immature fruit is higher than in half mature or mature fruit (Wills et al., 1989).

Up to 10 days storage at 12°C, the texture of late harvested 'Buoi' mangoes (both firmness and crushing stress) significantly ($P < 0.05$) declined compared with early harvested fruit. After 10 days storage this difference disappeared. The results show that soluble solids content in early harvested fruit were lower than in mid- and late harvested fruit (Appendix 2-Table 2.3), and in first 10 days this difference was greater than after 10 days storage. The soluble solids content was found to be correlated with fruit texture as reported by several researchers (Medlicott et al., 1988; Medlicott et al., 1990; Seymour et al., 1990). The authors reported that there was lower SSC, but higher firmness in immature fruit than in half mature or mature fruit. No differences in SSC were found between the mid and late harvested fruit.

Harvest date affected the susceptibility of fruit to chilling injury in 'Buoi' mangoes. Chilling injury was more serious in early harvested fruit than in mid and late harvested fruit (Figure 4.8). This can be explained by the fact that developing plant organs undergo constant chemical, physical, and physiological changes as long as they are attached. It is to be expected, therefore, that stage of development would have some impact on development of chilling injury symptoms. Since many symptoms of chilling injury involve alterations of normal ripening, it is commonly thought that ripe fruit are more resistant to chilling injury than unripe fruit (Pantastico et al., 1975; Saltveit et al., 1990; Weis et al., 1993). Medlicott et al. (1990) also showed that immature mango fruit was more susceptible to chilling injury than half-mature and mature fruit.

After 4 days ripening at 25°C, fruit SSC, chilling injury and eating quality were higher than at the time removal from cold storage, but acidity was lower. There was no significant ($P < 0.05$) difference in SSC in 'Buoi' mangoes between three different harvests. This result was different with the result reported by Medlicott et al. (1990) on 'Keitt' mangoes. The authors showed that SSC in late harvested ' Keitt' mangoes was higher than in early harvested fruit. The harvest date did not significantly affect the total acidity, and eating quality.

After ripening, the incidence of chilling injury in fruit was higher than at the time of removal from cold storage. Figure 4.12 shows that after 20 days storage at 12°C followed by ripening , only early harvested fruit were slightly affected (<1 %). After 25 days storage at 12°C and ripening, The incidence of chilling injury increased significantly, and was higher in early harvested fruit was significantly ($P < 0.05$) higher than in later harvested fruit. Chilling injury may lead to development of off-flavour and reduction of other fruit quality attributes (Morris, 1982; Saltveit et al., 1990). This could partly explain to the reduction in fruit eating quality after 25 days storage, especially in early harvested fruit.

4.6 Conclusions

Most of the postharvest quality attributes of 'Buoi' mangoes during storage at 12°C (RH 85-90%) were affected by storage time, while only some of these were found to vary with harvest dates. Increasing storage time led to increase in weight loss, peel and pulp colour, and chilling injury, but declined in flesh firmness and crushing stress, and total acidity. Soluble solids content and eating quality increased up to around 20 days, but after that they declined.

The early harvested fruit lost more weight compared with the mid and late harvested fruit. There was no significantly difference in weight loss between mid and late harvested fruit. The harvest date significantly affected flesh firmness and crushing stress of mangoes only in the first 10 days storage. Chilling injury appeared after 20 days storage at 12°C in early harvested fruit. This incidence increased with increasing storage time. The fruit after ripening were severed chilling injury more serious than those removal from cold storage.

The other postharvest quality attributes seem to be not affected by harvest date. There was no significant differences in peel and pulp colour, total acidity and eating quality between early and late harvested fruit (at the time removal from cold storage or after ripening). Up to 10 days storage soluble solids content in early harvested fruit was significantly lower than in mid- and late harvested fruit, however this difference disappeared later.

Compared to fruit removed from cold storage, ripened fruit were higher in SSC but lower in total acidity. The maximum value of SSC after removal from cold storage was 12.32% (mid- harvested fruit after 20 days storage, Appendix 2-Table 2.1), while this value after ripening was 13.85% in late harvested fruit after 20 days storage and 4 days ripening (Appendix 2-Table 2.2). On the other hand, the minimum values of total acidity after removal from cold storage and after ripening were 0.53% (Appendix 2-Table 2.1) and 0.31% (Appendix 2-Table 2.2), respectively.

According to the above findings, 'Buoi' mangoes harvested for long term cold storage, for example for export or long distance markets, should be harvested in the mid or late season rather than in early season in order to reduce chilling injury incidence and weight loss of fruit.

CHAPTER 5

EFFECTS OF STORAGE TEMPERATURE AND LENGTH OF STORAGE ON QUALITY ATTRIBUTES OF 'BUOI' MANGOES

5.1 Introduction

Storage temperature is the most important environmental factor that influences the deterioration rate of horticultural produce. Temperature management is therefore the most important tool for extending the shelf-life of fresh horticultural commodities (Kader, 1992). Lowering the temperature retards biological and physiological processes such as aging due to ripening, softening, and textural and colour changes; undesirable metabolic changes and respiratory heat production: moisture loss and the wilting that results; spoilage due to invasion by bacteria and fungi (Hardenburg et al., 1986; Kader, 1992; Wills et al., 1989). However, exposure of the commodity to low temperatures can result in physiological disorders such as freezing injury, chilling injury, and the other storage disorders such as scald and internal browning. The storage life of produce is highly variable and can be related to a wide range of respiration rates among different tissues. In general there is an inverse relation between respiration rate and storage life so that commodity with a low respiration rate generally keeps longer (Wills et al., 1989). Fidler (1973) showed that even a change in temperature of 1°C can have a significant effect on storage life of apples.

Veloz et al. (1977) reported that the weight loss in cool-stored 'Kent' mangoes was proportional to the temperature and duration of storage. Lowering refrigeration temperature caused significant reduction in weight loss of fruit. Vazquez-Salinas and Lakshminarayana (1985) also showed that the weight loss in 'Haden', 'Irwin', 'Kent', and 'Keitt' after 2 or 10 days storage at 25 and 28°C was significantly higher than at 16 and 22°C.

The effects of storage temperatures on compositional changes in mango fruit during ripening at different storage temperatures have been reported by O'Hare (1995) on 'Kensington'; Vazquez-Salinas and Lakshminarayana (1985) on 'Haden', 'Irwin', 'Kent' and 'Keitt' ; and Veloz et al. (1977) on 'Kent' mangoes. Vazquez-Salinas and Lakshminarayana (1985) showed that the reduction in acidity was generally slower in fruits stored at 16°C as compared to higher temperatures, 25 and 28°C, while there was no significant variation noticeable with regard to soluble solids content.

McLauchlan and Wells (1994) reported that 'Kensington' mangoes stored at 13°C ripened significantly during the first week of storage, indicating that 13°C is a short-term holding temperature only. Fruit stored at 10°C coloured slowly in store while colour of fruit stored at 7°C remained static. It was recommended that a temperature of 10°C can be used for storage of 'Kensington' mangoes for up to 3 weeks; while 7°C is suitable for storage up to 2 weeks after which ripe colour development may be retarded. Chaplin et al. (1991) reported that 'Kensington' mangoes held at 1, 5, 10, and 15°C remained fully firm after 1 week of storage. The extent of subsequent softening was related to the storage temperature. The fruit at 15°C were fully soft after 3 weeks of storage while those at 1 or 5°C were only slightly soft. Fruit at 10°C had intermediate softness. External visual symptoms of chilling injury were apparent on fruit after removal from 1 week of storage at 1 or 5°C. CI symptoms became more severed as fruit ripened at 20°C and with increased storage time. No visual symptoms of chilling injury were apparent in fruit stored up to 3 weeks at 10 or 15°C.

Beside storage temperature, length of storage is also a very important factor affecting posthavest quality attributes of commodity. Paull (1994) indicated that there is not an exact fruit specific reciprocal relationship between temperature and time, and that it takes a longer time at a higher temperature to develop chilling injury than at a lower temperature. Collins and Tisdell (1995) investigated the influence of storage time and temperature on chilling injury in Fuyu and Suruga persimmon (*Diospyros kaki* L.) grown in subtropical Australia and they also showed that incidence of chilling injury was dependent on temperature and storage time. The actual relationship between storage temperature and duration can very with variety, preharvest conditions, stage of ripeness, and postharvest treatments (Paull, 1994). For 'Kent' mango Veloz et al. (1977) reported that fruits were stored at 8, 10, 13°C, the development of damage through chilling injury after storage for 10, 16, and 24 days respectively. However, Chaplin et al. (1991) indicated that 'Kensington' mango fruit grown in Australia were stored at 10°C up to 4 weeks without visual symptom of chilling injury. The results on 'Buoi' mangoes presented in Chapter 4 also show the importance of storage duration on fruit quality from different harvests during season. Also highlight the overall literature findings in Chapter 2 which showed significant cultivar variability in storage temperature requirements.

The objectives of the study reported in this chapter was evaluate the effect of storage temperature and length of storage on postharvest quality attributes of "Buoi' mangoes. In addition, regression models for predicting postharvest quality of mangoes as a function of storage temperature and time were developed.

5.2 Experimental Design

Mature, green 'Buoi' mangoes were harvested on 24/3/1997 from an orchard in Hoa Loc area, Cai Be District, Tien Giang Province, Vietnam and transferred to laboratory at the Posthavest Technology Institute (PHTI) in Hochiminh City. Fruit for testing were selected on the basis of freedom from mechanical damage, pests, and diseases.

Fruit were harvested based on skin colour and uniform size (Chapter 3). There were 480 fruits randomly selected and divided into 4 groups. A sample of 120 fruits were stored at each of the following cool-store temperatures:7°C, 12°C, 17°C (± 1°C, RH 85-90%,) and ambient temperature (27°C). Twenty fresh fruit samples were assessed for quality attributes such as fruit firmness, crushing stress, skin and pulp colour, SSC, total acidity, and eating quality as described in Chapter 3. At 5-day intervals, a sub-sample of 20 fruits were removal from cold storage and weighed for calculating weight loss rate. After that ten fruit were assessed for fruit firmness, crushing stress, skin and pulp colour, SSC, acidity, chilling injury and eating quality as described in Chapter 3. Another sub-sample of ten fruits were transferred to temperature (25°C, RH 80-85%) in laboratory room for ripening and assessed SSC, acidity, chilling injury and eating quality.

5.3 Data Analysis

Data on weight loss rate, fruit firmness, crushing stress, skin and pulp colour, soluble solids content, acidity, and eating quality were subjected to analysis of variance, and the means were compared using least significant difference (SAS, 1995). Excel 5.0 for Windows and SAS statistical package were used for graphs and regression analyses.

5.4 Results

5.4.1 Effect of storage temperature and length of storage on fruit quality

Weight loss

In all 4 storage temperatures, increasing storage time led to a significant ($P < 0.05$) increase in weight loss (Figure 5.1); however, the longer 'Buoi' mangoes were kept in storage the faster they lost their weight. Storage temperature also significantly ($P < 0.05$) affected the weight loss (Figure 5.1). The loss in weight increased very fast with increase storage temperature, particularly in high temperature (ambient temp.). After 25 days

'Buoi' mangoes lost only 5.54% when stored at 7°C, but lost 11.65% when stored at 17°C. Fruit stored at ambient temperature lost 16.02% only in 15 days of storage. Regression analyses showed that the relationships between weight loss rate and storage time in different storage temperatures were linear (Table 5.1). The very high regression coefficients indicated that overall length of storage was a good predictor of weight loss at each storage temperature. Equation (5) in Table 5.1 with $R^2 = 0.83$ suggested that postharvest factors, length of storage and storage temperature were good predictors for the weight loss rate.

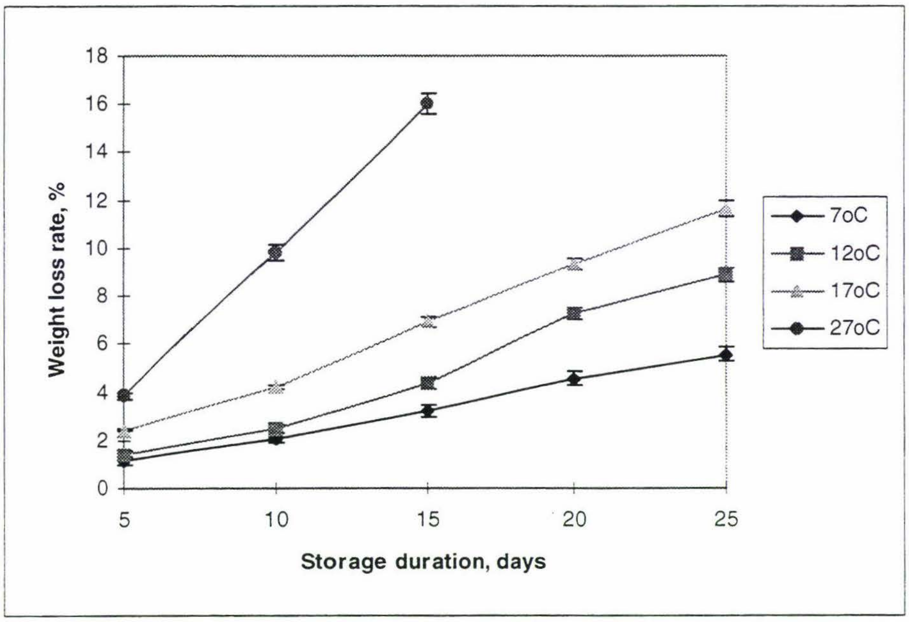

Figure 5.1 Effects of storage temperatures on weight loss rate of 'Buoi' mangoes.

Using equation 5 in Table 5.1 the response surface of weight loss of 'Buoi' mangoes when stored at different storage temperature and time is shown in Figure 5.2. The response surface shows that increasing storage temperature and/or storage time lead to significantly increase in weight loss.

Table 5.1 The relationships between weight loss rate (W_t, %) of 'Buoi' mangoes and storage time (T, days) and at different storage temperature (t,°C).

Storage temp., °C	Weight loss rate, %	Regression coefficient, R^2
7	W_{t7} = - 0.1356 + 0.02278 T (1)	0.9558
12	W_{t12} = - 1.0263 + 0.395 T (2)	0.9533
17	W_{t17} = - 0.1602 + 0.4715 T (3)	0.9768
27	W_{t27} = - 2.2565 + 1.216 T (4)	0.9820
7 - 27	W_t = -6.18 + 0.411 T + 0.429 t (5)	0.8300

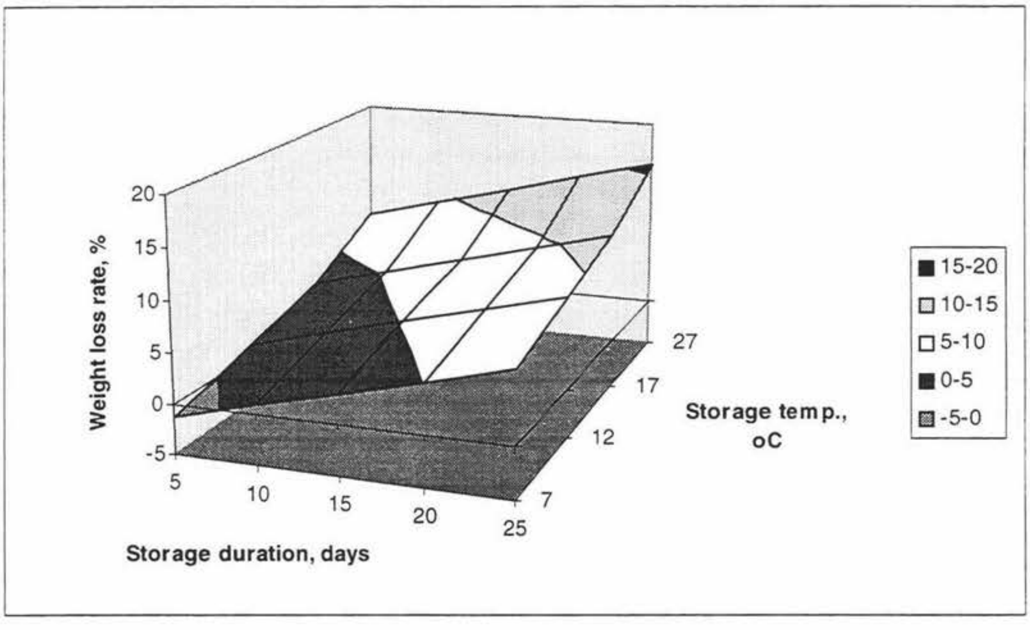

Figure 5.2 Response surface of weight loss of 'Buoi' mangoes stored at different temperatures.

Peel and pulp colour

Yellowiness of the fruit peel and pulp increased during storage in all 4 treatments (Figure 5.3 and 5.4), however, the rate of development of yellowiness was faster at higher storage temperatures. Figure 5.3 shows that after 25 days storage peel colour at 7°C was still half green (colour index = 3) while at 17°C already full yellow (colour index = 4.6). Fruit stored at 27°C became full yellow (colour index = 5) only after 15 days. Figure 5.4 shows that the change in pulp colour were similar to the change in peel colour with development yellow colour from white colour. The effects on peel and pulp colour during storage at different temperatures are described in the linear relationships in Table 5.2 and 5.3. The results in Table 5.2 and 5.3 show that at low storage temperature (7°C) length of storage is a poor predictor of peel and pulp colour, however, increasing storage temperature led to improve this predictor. In the temperature range 7 - 27°C (equation 5 in Table 5.2 and Table 5.3) length of storage and storage temperature were good predictors for peel and pulp colour (R^2 =0.922 and 0.913).

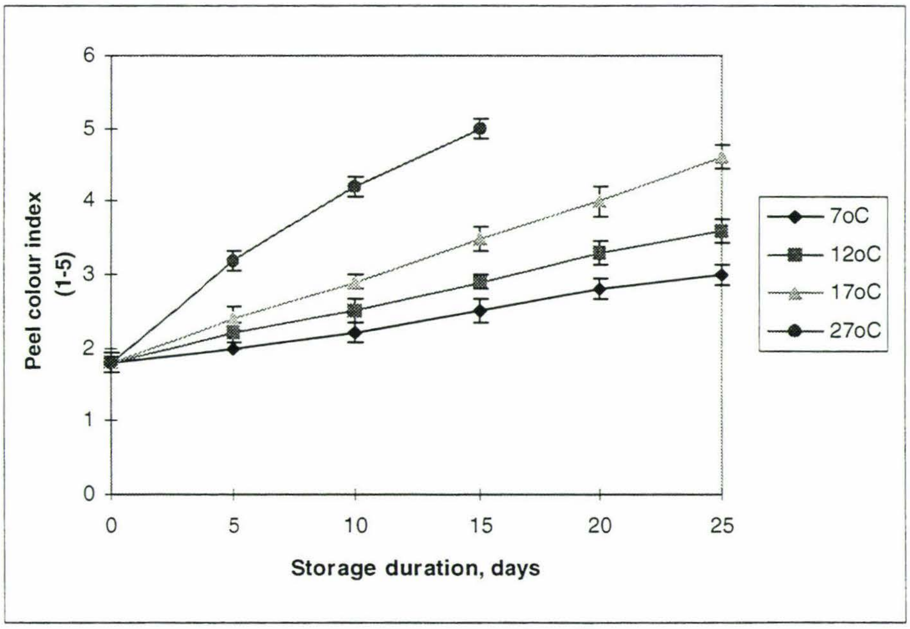

Figure 5.3 Effects of storage temperature on peel colour of Buoi' mangoes

Table 5.2 The relationships between peel colour (C_{pe}) of 'Buoi' mangoes and storage time (T, days) at different storage temperatures (t,°C).

Storage temp., °C	Peel colour	Regression coefficient, R^2
7	C_{pe7} = 1.7619 + 0.0497 T (1)	0.5357
12	C_{pe12} = 1.8095 + 0.0726 T (2)	0.6741
17	C_{pe17} = 1.8143 + 0.1109 T (3)	0.7954
27	C_{pe27} = 1.96 + 0.212 T (4)	0.9076
7 -27	C_{pe} = 0.446 + 0.0894 T + 0.104 t (5)	0.9220

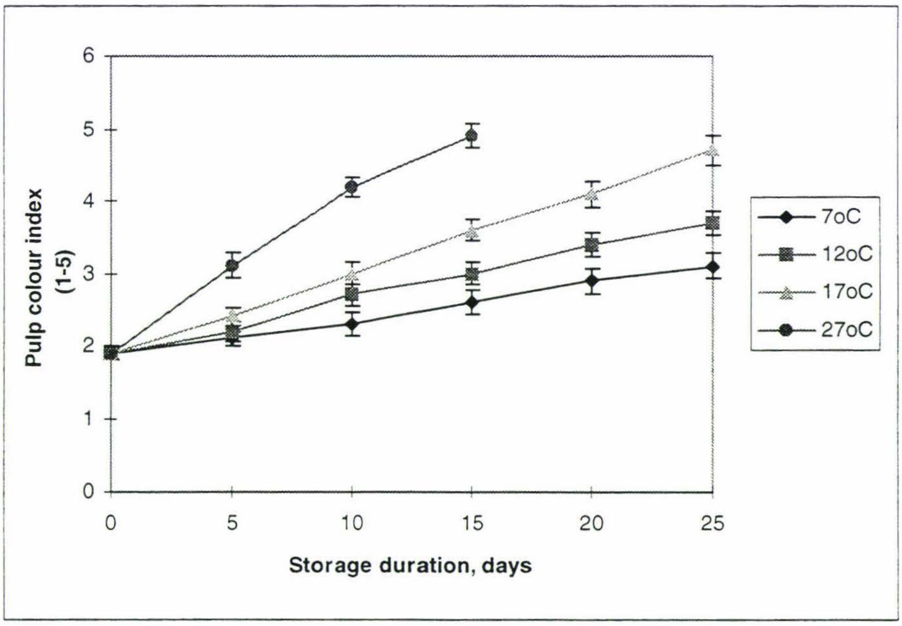

Figure 5.4 Effects of storage temperature on pulp colour of Buoi' mangoes.

Table 5.3 The relationships between pulp colour (C_{pu}) of 'Buoi' mangoes and storage time (T,days) at different storage temperatures (t,°C).

Storage temp., °C	Pulp colour	Regression coefficient, R^2
7	$C_{pu7} = 1.8619 + 0.0497\ T$ (1)	0.5705
12	$C_{pu12} = 1.8952 + 0.0737\ T$ (2)	0.7208
17	$C_{pu17} = 1.8762 + 0.1126\ T$ (3)	0.7900
27	$C_{pu27} = 2.01 + 0.202\ T$ (4)	0.8798
7 - 27	$C_{pu} = 0.606 + 0.0862\ T + 0.0962\ t$ (5)	0.9130

There was no significant ($P < 0.05$) difference in the peel (up to 10 days storage) and pulp colour (up to 20 days) between fruit stored at 7°C and 12°C. The effects of storage temperature on peel and pulp colour of 'Buoi' mangoes are shown in Figure 5.5 and 5.6. Figure 5.5 shows that after 15 days stored at 7°C peel colour of 'Buoi' mangoes is still in green-yellow colour (Figure 5.5; fruit on the right) while the fruit stored at ambient temperature already change to full yellow (Figure 5.5; fruit on the left). Similar to peel colour, fruit pulp stored at 7°C still in white-yellow colour (Figure 5.6; fruit on the right), while fruit stored at ambient temperature become orange colour (Figure 5.6; fruit on the left).

Using equation 5 in Table 5.2 and 5.3 the response surfaces of peel and pulp colour of 'Buoi' mangoes when stored at different storage temperatures and time are shown in Figure 5.7 and 5.8. The response surfaces show that increasing storage temperature and/or storage time lead to significantly increase the development of yellowness in peel and pulp colour.

Figure 5.5 Peel colour of 'Buoi' mangoes after 15 days storage at different temperatures : From right to left: 7, 12, 17 and 27°C.

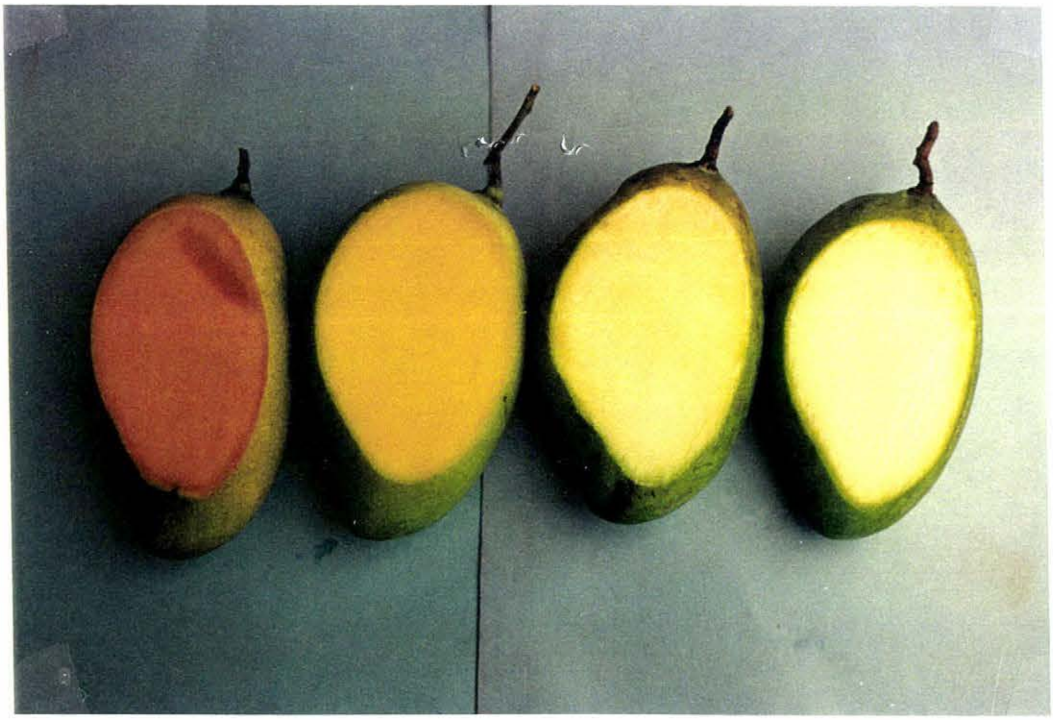

Figure 5.6 Pulp colour of 'Buoi' mangoes after 15 days storage at different temperatures : From right to left: 7, 12, 17 and 27°C.

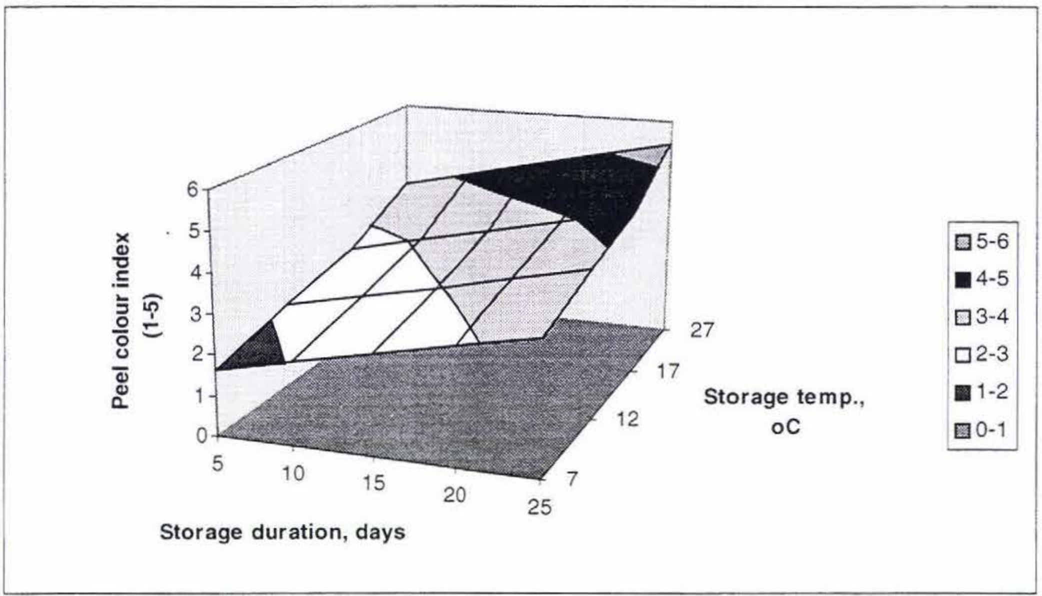

Figure 5.7 Response surface of peel clour of 'Buoi' mangoes stored at different temperatures.

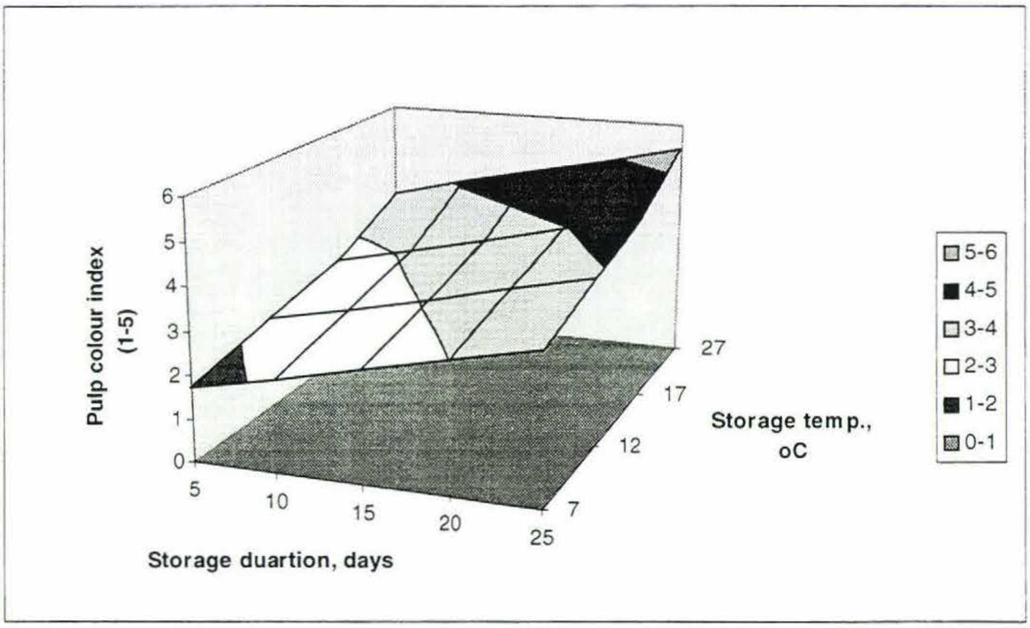

Figure 5.8 Response surface of pulp colour of 'Buoi' mangoes stored at different temperatures.

Texture

The effect of length of storage and storage temperature on flesh firmness and crushing stress of 'Buoi' mangoes is shown in Figure 5.9 and 5.10. Flesh firmness significantly ($P < 0.05$) declined with increase storage time. Crushing stress in fruit stored at 7°C significantly ($P < 0.05$) reduced with increase storage time, however, fruit stored at the other storage temperatures significantly reduced crushing stress only up to 20 days storage . There was no significant difference in crushing stress between fruit stored 20 and 25 days.

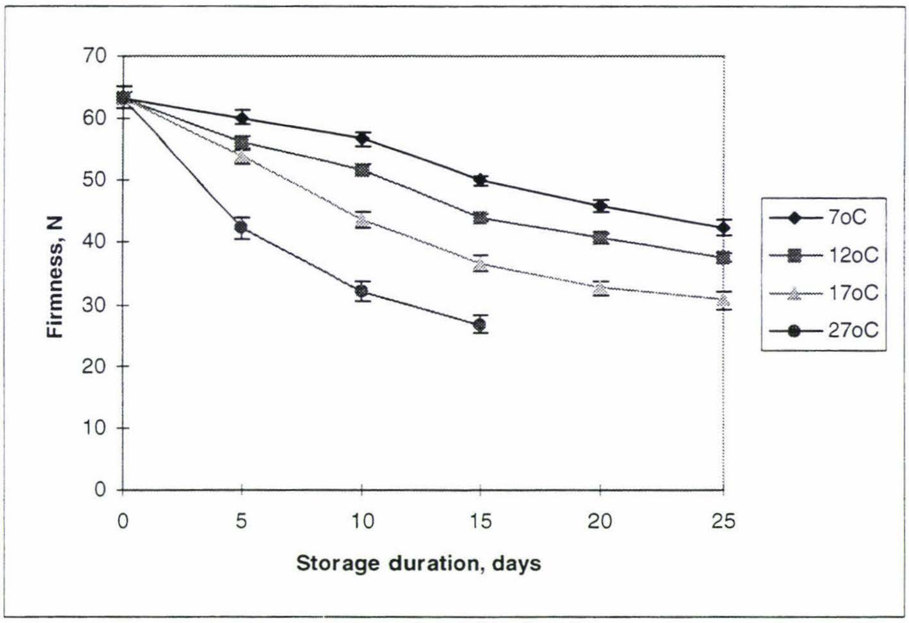

Figure 5.9 Effects of storage temperature on flesh firmness of Buoi' mangoes.

The firmness and crushing stress were highly dependent on storage temperature. Increasing storage temperature led to a significant ($P < 0.05$) decline in firmness and crushing. After doing regression analyses the relationships between firmness and storage time (Table 5.4), between crushing stress and storage time (Table 5.5) in different storage temperatures are quadratic relationships. The regression coefficients in Table 5.4 and 5.5 very high show that length of storage is good predictor for fruit texture. Regression coefficients for equation 5 in Table 5.4 and 5.5 are 0.9646 and 0.9766 indicate that storage temperature and storage time were good predictors for peel and pulp colour.

Table 5.4 The relationships between flesh firmness (P,N) of 'Buoi' mangoes and storage time (T,days) at different storage temperatures (t,°C).

Storage temp., °C	Flesh firmness	Regression coefficient, R^2
7	$P_7 = -0.8823\,T + 64.129$ (1)	0.8439
12	$P_{12} = 0.0232\,T^2 - 1.6158\,T + 63.511$ (2)	9.0500
17	$P_{17} = 0.0398\,T^2 - 2.3432\,T + 63.939$ (3)	0.9292
27	$P_{27} = 0.157\,T^2 - 4.761\,T + 63.095$ (4)	0.9759
7 - 27	$P = 81.1950 - 1.9555\,T - 1.2545\,t + 0.030446\,T^2 + 0.003136\,t^2$ (5)	0.9766

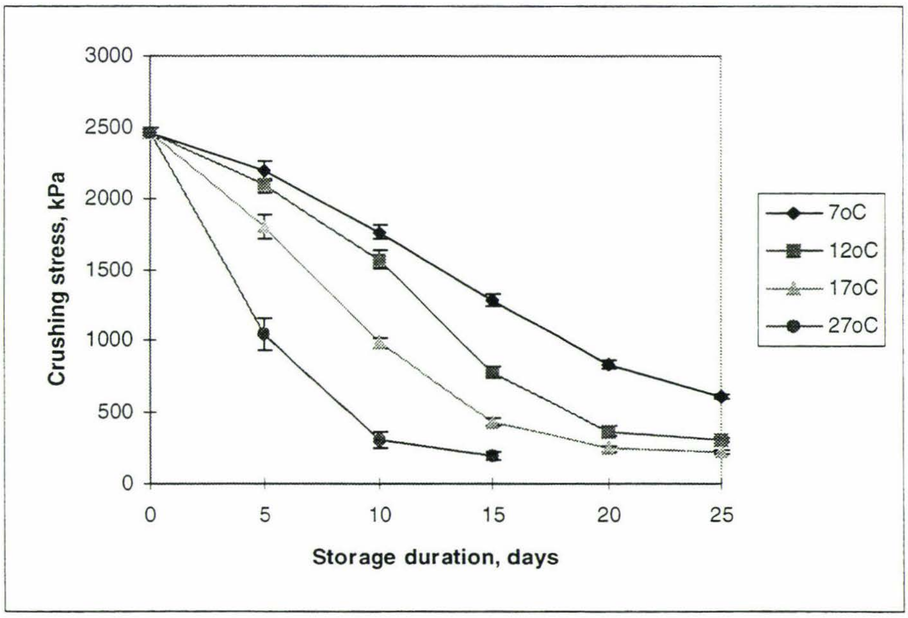

Figure 5.10 Effects of storage temperature on crushing stress of 'Buoi' mangoes.

Table 5.5 The relationships between crushing stress (P_{cr}, kPa) of 'Buoi' mangoes and storage time (T,days) at different storage temperatures (t,°C).

Storage temp., °C	Crushing stress	Regression coefficient, R^2
7	P_{cr7} = 0.42 T^2 - 91.63 T + 2588.3 (1)	0.9669
12	P_{cr12} = 1.9011 T^2 - 145.81 T + 2653.8 (2)	0.9581
17	P_{cr17} = 4.3941 T^2 - 205.93 T + 2606.2 (3)	0.9851
27	P_{cr27} = 13.897 T2 - 364.22 T + 2538.9 (4)	0.9935
7 - 27	P_{cr} = 3565.1337 - 178.8276 T - 62.0864 t + 3.202249 T^2 + 0.06072 t^2 (5)	0.9646

Using equation 5 in Tables 5.4 and 5.5, respectively, the response surfaces of flesh firmness and crushing stress of 'Buoi' mangoes when stored at different storage temperatures and time are shown in Figure 5.11 and 5.12. The response surfaces in Figure 5.11 and 5.12 indicate that at beginning of storage fruit reduced flesh firmness and crushing stress very fast up to 15 days, after that slow down the rate of softening. At high storage temperature and long storage time the texture will change not so much if increase storage temperature or/and storage time.

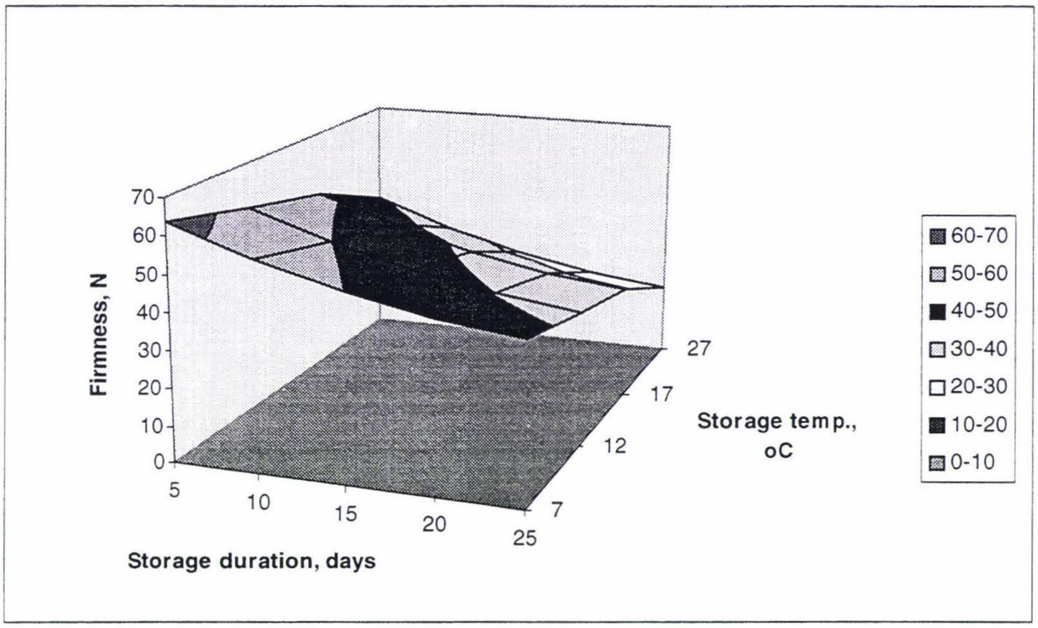

Figure 5.11 Response surface of firmness of 'Buoi' mangoes stored at different temperatures.

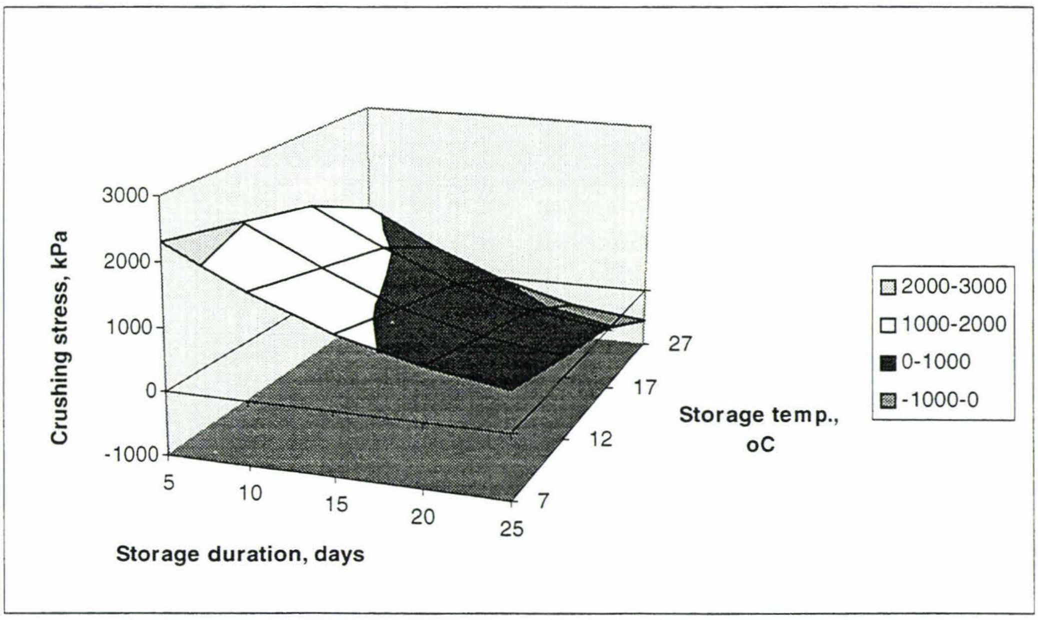

Figure 5.12 Response surface of crushing stress of 'Buoi' mangoes stored at different temperatures.

Soluble solids content

In all temperature treatments, soluble solids content (SSC) significantly ($P < 0.05$) increased up to 20 days storage, but after that declined (Figure 5.13). Soluble solids content was also found significantly ($P < 0.05$) increased with increase storage temperature from 7 to 17°C. On the fifth day of storage, there was no significant ($P < 0.05$) difference in SSC between fruit stored at 7°C and 12°C, but significant difference between fruit stored at 12°C and 17°C or 17°C and 27°C. 'Buoi' mangoes stored 10 days or longer significantly ($P < 0.05$) increased in SSC with increase storage temperature. However, Figure 5.6 shows that the highest SSC in fruit stored at ambient temperature (12.56%) was lower than in fruit stored at 17°C (12.91%). The relationships between SSC and storage duration at different temperature treatments are quadratic relationships (Table 5.6). The results in Table 5.6 show that all regression coefficients are high (highest = 0.9454 at storage temperature 17°C and lowest = 0.7911 at storage temperature 7°C). It means that length of storage and also storage temperature were good predictors for soluble solids content.

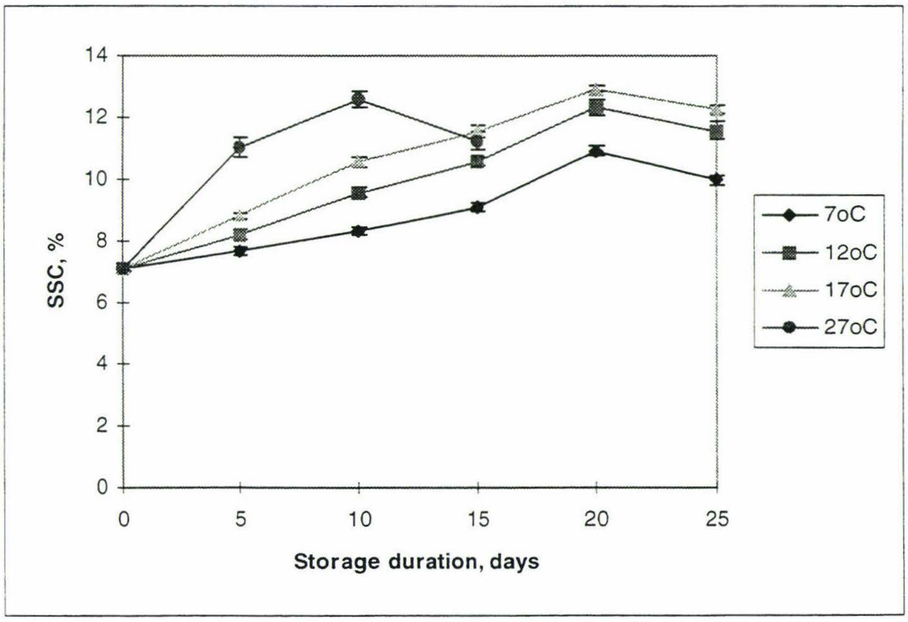

Figure 5.13 Effects of storage temperature on SSC of Buoi' mangoes.

Table 5.6 The relationships between SSC (S,%) of 'Buoi' mangoes and storage time (T,days) at different storage temperatures (t,°C).

Storage temp., °C	SSC	Regression coefficient, R^2
7	$S_7 = -0.0021\,T^2 + 0.1968\,T + 6.8757$ (1)	0.7911
12	$S_{12} = -0.0057\,T^2 + 0.3481\,T + 6.851$ (2)	0.8716
17	$S_{17} = -0.0096\,T^2 + 0.4641\,T + 6.9211$ (3)	0.9454
27	$S_{27} = -0.0628\,T^2 + 1.2032\,T + 7.201$ (4)	0.8697
7 - 27	$S = 4.7990 + 0.2966\,T + 0.1824\,t - 0.004764\,T^2 + 0.001068\,t^2$ (5)	0.8543

Using equation 5 in Table 5.6 the response surfaces of SSC of 'Buoi' mangoes when stored at different storage temperatures and time is shown in Figure 5.14. The response surface in Figure 5.14 suggests that increasing storage temperature or/and storage time causes increase in SSC.

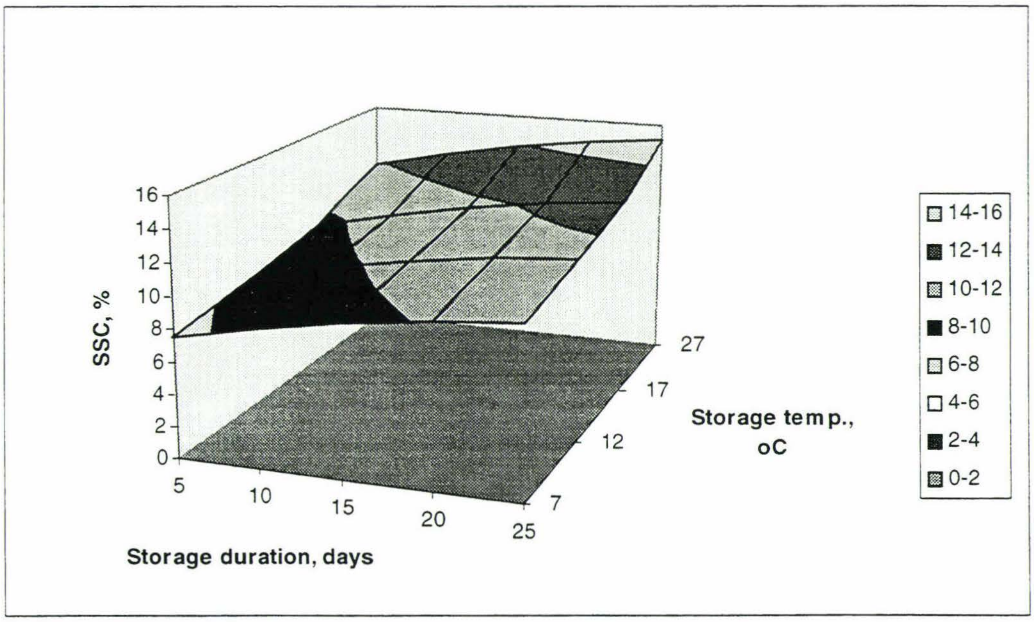

Figure 5.14 Response surface of SSC of 'Buoi' mangoes stored at different temperatures.

Total acidity

Total acidity in 'Buoi' mangoes significantly ($P < 0.05$) decreased during storage time (Figure 5.15). However, at high storage temperatures (17°C and ambient temperature) the total acidity reduced faster than at low temperatures (7°C and 12°C). Figure 5.15 shows that increasing storage temperature led to significantly ($P < 0.05$) reduce acidity in 'Buoi' mangoes. The effects of storage time on total acidity at different storage temperatures are quadratic relationships (Table 5.7). The regression coefficients very high, therefore, total acidity content could be predicted during storage by length of storage and storage temperature.

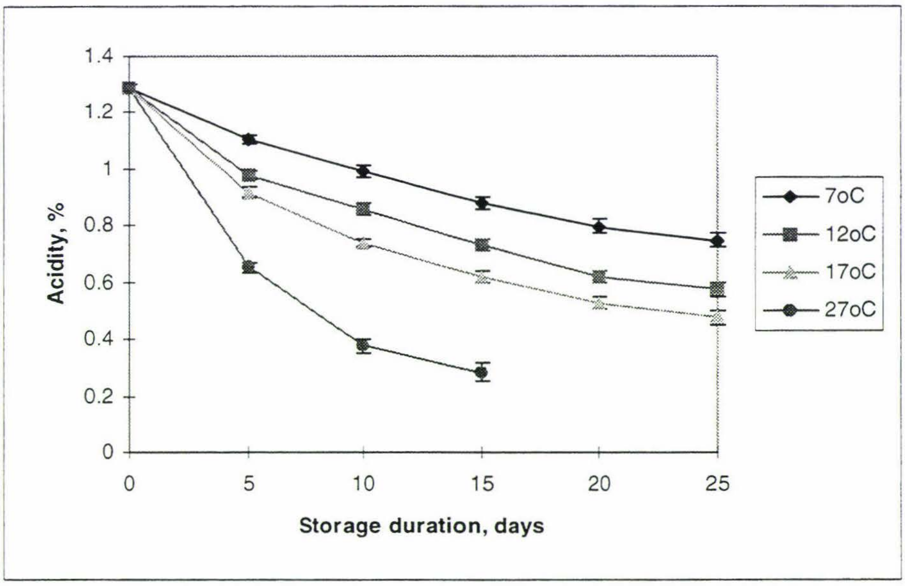

Figure 5.15 Effects of storage temperature on total acidity of Buoi' mangoes.

Table 5.7 The relationships between total acidity content (A, %) of 'Buoi' mangoes and storage time (T,days) at different storage temperatures (t,°C).

Storage temp., °C	Total acidity	Regression coefficient, R^2
7	$A_7 = 0.0005 T^2 - 0.0336 T + 1.2769$ (1)	0.8599
12	$A_{12} = 0.01 T^2 - 0.051 T + 1.2618$ (2)	0.9535
17	$A_{17} = 0.0014 T^2 - 0.0646 T + 1.2581$ (3)	0.9661
27	$A_{27} = 0.054 T^2 - 0.147 T + 1.2779$ (4)	0.9839
7 - 27	$A = 1.4986 - 0.0427 T - 0.0213 t + 0.000731 T^2 - 0.000194 t^2$ (5)	0.9786

Using equation 5 in Table 5.7 the response surfaces of total acidity of 'Buoi' mangoes when stored at different storage temperatures and time is shown in Figure 5.16. The response surface in Figure 5.16 shows that increasing storage temperature or/and storage time lead to reduce in total acidity.

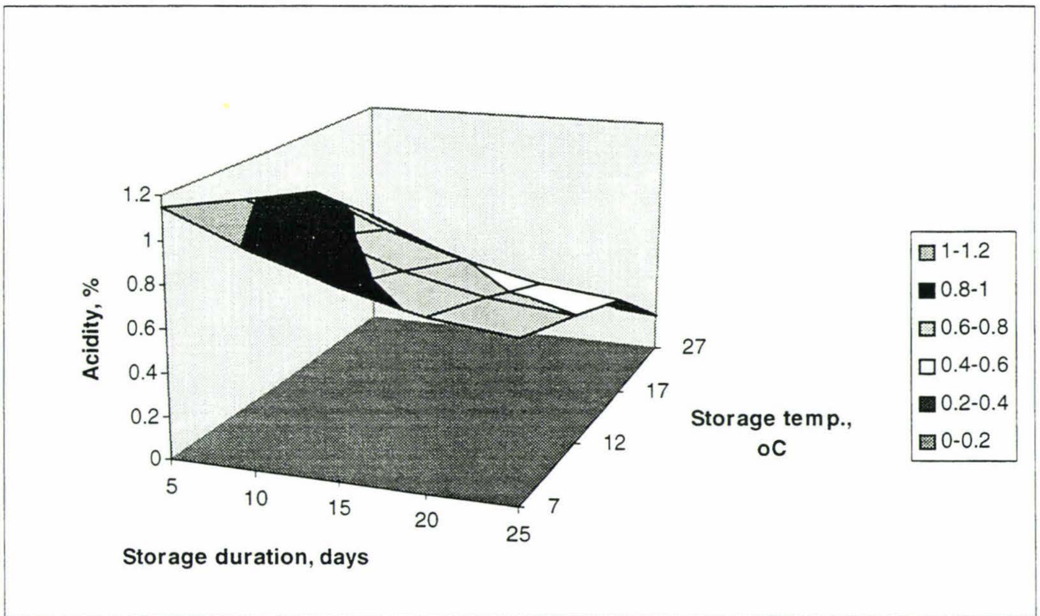

Figure 5.16 Response surface of total acidity of 'Buoi' mangoes stored at different temperatures.

Chilling injury

There was no evidence of chilling injury when fruit were stored at 17°C and at ambient temperature (Appendix 1). The effects of storage temperature and length of storage on chilling injury are shown in Figure 5.17. Chilling injury appeared after 15 days storage at 7°C and 20 days at 12°C, but was only a trace. This incidence significantly ($P < 0.05$) developed with increase storage time and/or with decrease storage temperature. The relationships between chilling injury and storage at storage temperature 7°C and 12°C were linear equations (Table 5.8). However, regression coefficient at storage temperature of 12°C was very low ($R^2 = 0.4583$). Therefore, at storage temperature of 12°C, the length of storage is poor predictor for chilling injury. This can be partly attributed to the late development of chilling injury in fruit which occurred over 20 days in storage.

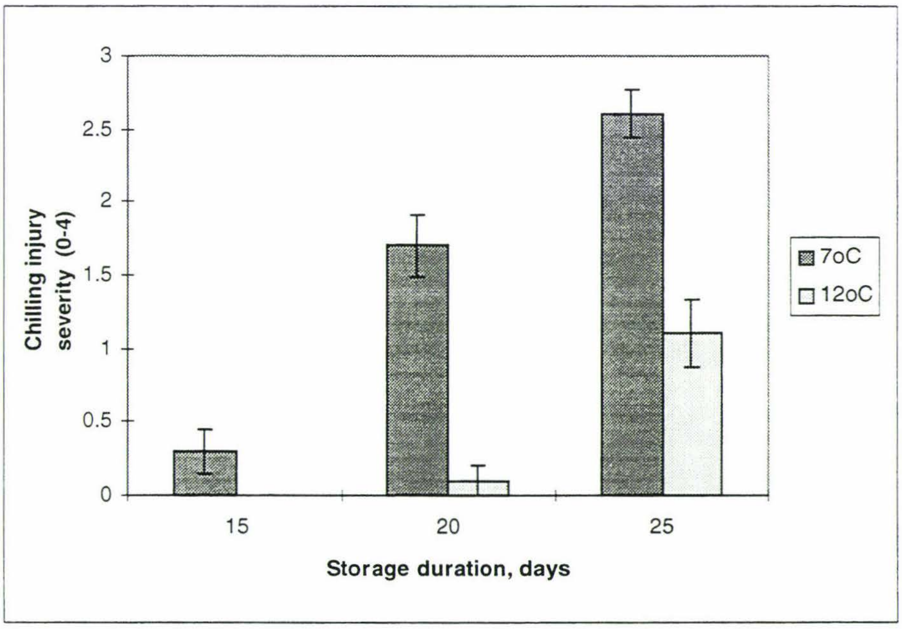

Figure 5.17 Effects of storage temperature on chilling injury of Buoi' mangoes.

Table 5.8 The relationships between chilling injury (CI) of 'Buoi' mangoes and storage time (T,days) at different storage temperatures (t,°C).

Storage temp., °C	Chilling injury index	Regression coefficient, R^2
7	$CI_7 = 0.23\,T - 3.0667$ (1)	0.7458
12	$CI_{12} = 0.11\,T - 1.8$ (2)	0.4583
7-12	$CI = -0.28 + 0.170\,T - 0.227\,t$ (3)	0.9000

Using equation 3 in Table 5.8 the response surface of chilling incidence of 'Buoi' mangoes when stored at different storage temperatures and time is shown in Figure 5.18. The response surface in Figure 5.18 shows that fruit are not affected by chilling injury if storage duration is shorter than 15 days or storage temperature equal or greater than 17°C.

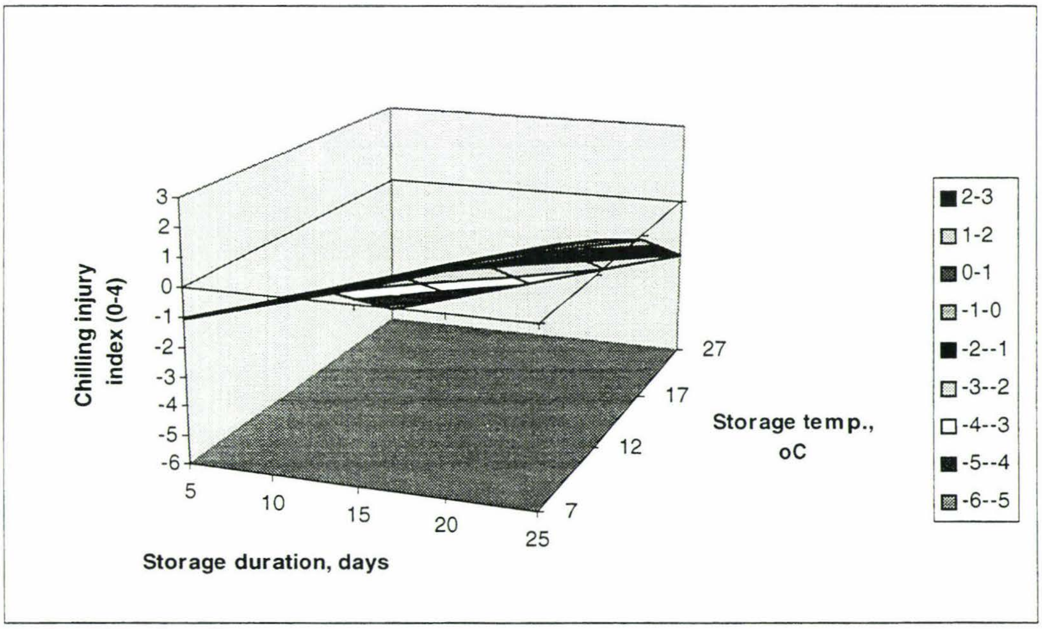

Figure 5.18 Response surface of chilling injury of 'Buoi' mangoes stored at different temperatures.

Eating quality

The effects of storage temperature and storage time on eating quality (EQ) is shown in Figure 5.19. Eating quality at storage temperature 7, 12, 17°C significantly (P < 0.05) increased with increase storage time up to 20 days, but decreased after that, while fruit stored at ambient temperature had the best EQ after 10 days of storage. Eating quality was found affected by storage temperature. Up to 10 days of storage, there was no significant (P < 0.05) difference in EQ between fruit stored 7°C and 12°C, but significant difference between fruit stored in 12°C and 17°C or 17°C and ambient temperature. Fruit stored 15 and 20 days gave the best EQ at storage temperature 17°C, however, after 25 fruit stored at 12°C gave the best EQ. The relationships between EQ and storage time at different temperatures were quadratic (Table 5.9). Table 5 shows that storage duration and storage temperature were good factors for predicting eating quality.

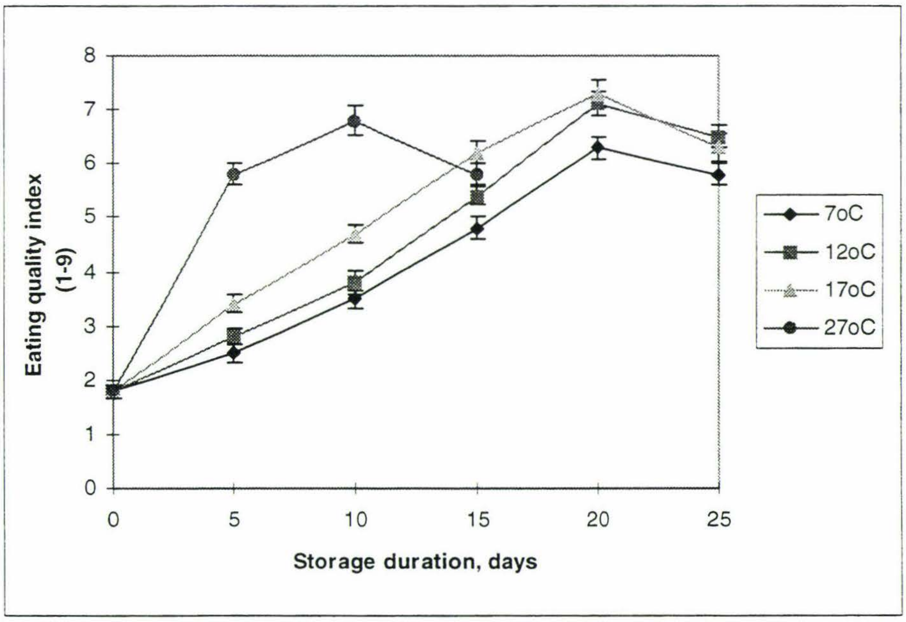

Figure 5.19 Effects of storage temperature on eating quality of Buoi' mangoes.

Table 5.9 The relationships between eating quality (E) of 'Buoi' mangoes and storage time (T,days) at different storage temperatures (t,°C).

Storage temp., °C	Eating quality	Regression coefficient, R^2
7	$E_7 = -0.0029\ T^2 + 0.2583\ T + 1.5429$ (1)	0.8489
12	$E_{12} = -0.0036\ T^2 + 0.3104\ T + 1.5214$ (2)	0.8589
17	$E_{17} = -0.0093\ T^2 + 0.4373\ T + 1.5786$ (3)	0.8633
27	$E_{27} = -0.05\ T^2 + 1.01\ T + 1.85$ (4)	0.8969
7 - 27	$E = 0.4496 + 0.3638\ T + 0.0475 - 0.006307\ T^2 + 0.002037\ t^2$ (5)	0.8236

The response surface of eating quality is shown in Figure 5.20. At first increasing storage duration or/and storage temperature resulted in a rapid increase in eating quality. However, at higher storage temperature and/or longer storage duration, the changes in eating quality was minimal.

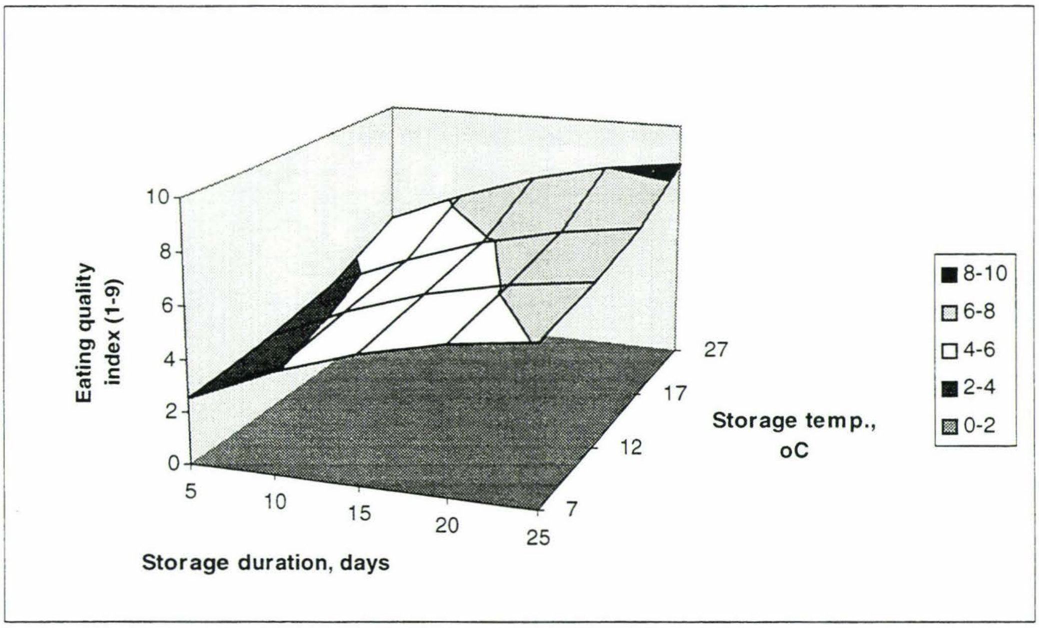

Figure 5.20 Response surface of eating quality of 'Buoi' mangoes stored at different temperatures.

Data on postharvest quality attributes of 'Buoi' mangoes stored at different temperatures during storage are presented in Appendix 3. The results of analysis of variance (ANOVA) of postharvest quality attributes and means are shown in Appendix 4.

5.4.2 Effect of storage temperature and storage time on fruit ripening

After ripening at 25°C, soluble solids content was higher in fruit stored at 17°C or 12°C compared to stored at 7°C or 27°C, particularly after 15 days storage or longer (Figure 5.21). SSC in fruit stored at 7°C or 17°C was highest after 15 days of storage (12.62 and 13.90%), while it was 20 days for fruit stored at 12°C (13.76%) and 10 days for ambient temperature (13.24%). Increasing storage time and storage temperature led to a reduction in total acidity (Figure 5.22). Similar to fruit removed from cold storage, ripened fruit suffered chilling injury only at storage temperatures of 7°C and 12°C, respectively (Figure 5.23). Maximum fruit eating quality occurred following storage at 17°C for 10 - 15 days or 12°C for 15 - 20 days (Figure 5.24). Figure 5.24 shows that fruit stored at ambient temperature had very poor eating quality if storage duration was 15 days or longer.

In comparison to fruit removed from cold store, ripening fruit at 25oC for 4 days significantly increased SSC accumulation (Figure 5.13 and 5.21) and a reduction in total acidity (Figure 5.15 and 5.22). Incidence of chilling injury in ripened fruit was more serious than in fruit removed from cold storage, especially fruit stored at 7°C (Figure 5.17 and 5.23). Eating quality were higher up to 15 days for storage temperature 7, 12, and 17°C; however, fruit stored at ambient temperature for 10 days and 17°C for 20 days had poor eating quality (Figure 5.19 and 5.24).

Data on postharvest quality attributes of 'Buoi' mangoes storage at different temperatures and ripening at 25°C for 4 days are shown in Appendix 3. The results of analysis of variance (ANOVA) of postharvest quality attributes and means are shown in Appendix 4.

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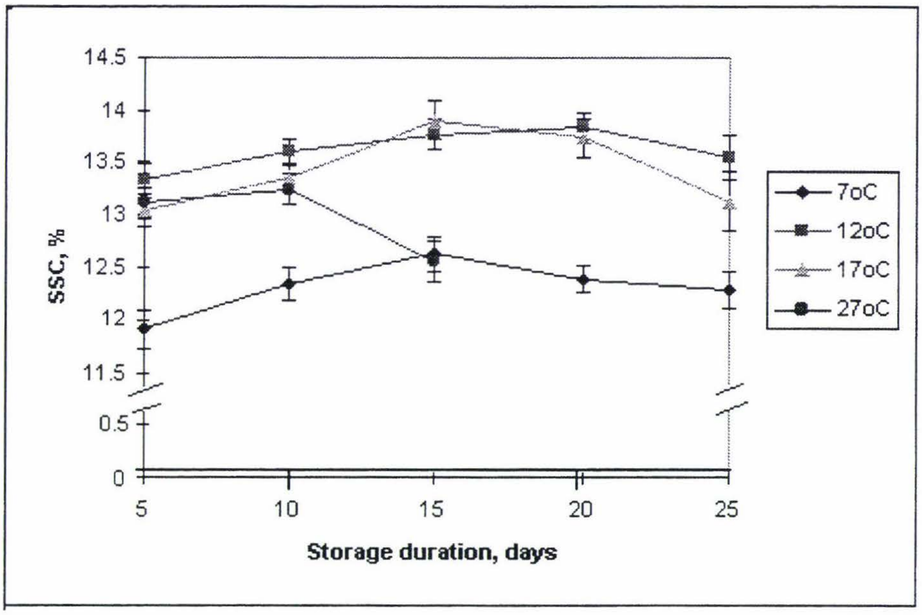

Figure 5.21 Effects of storage temperature on SSC of 'Buoi' mangoes after removal from cold storage and ripening for 4 days.

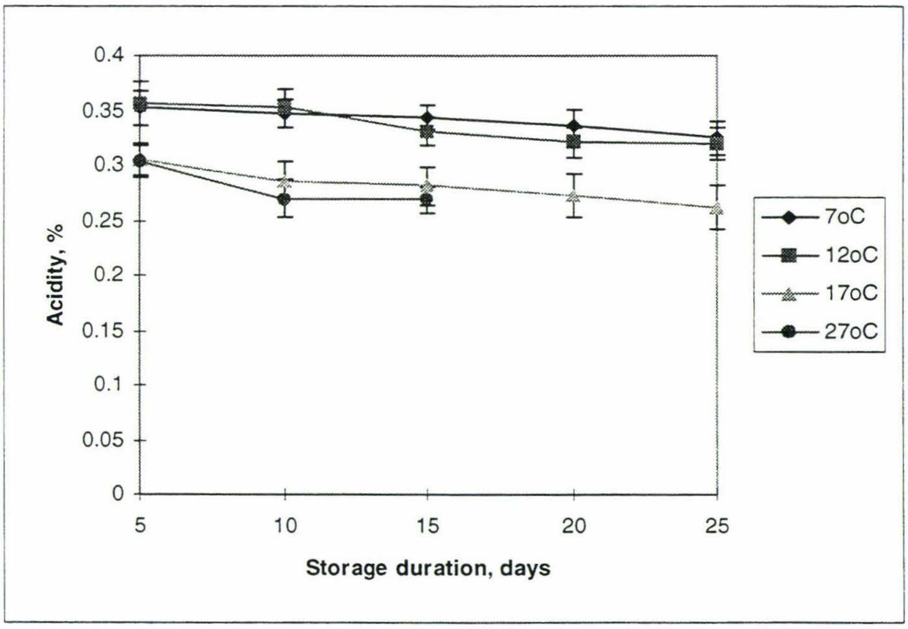

Figure 5.22 Effects of storage temperature on total acidity of 'Buoi' mangoes after removal from cold storage and ripening for 4 days.

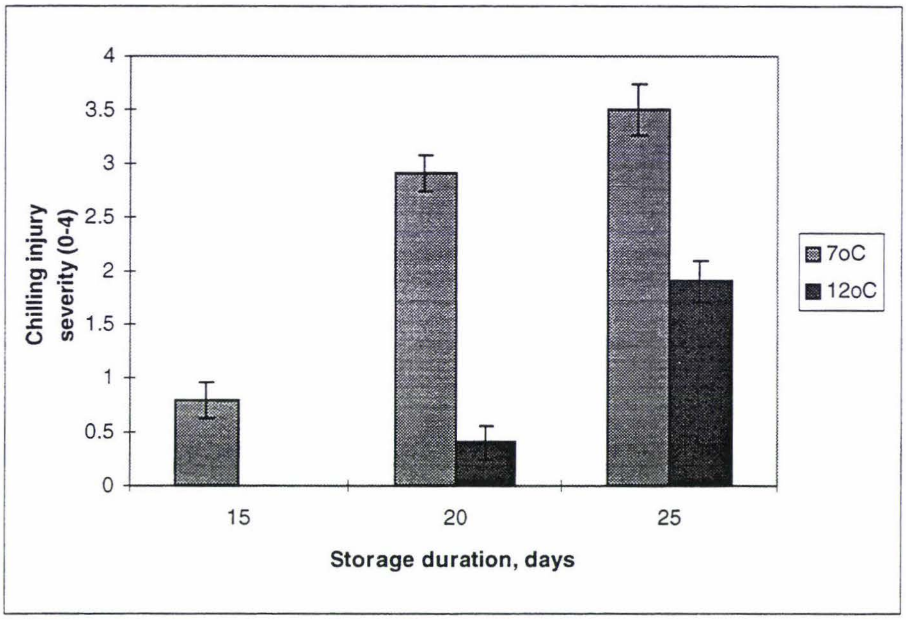

Figure 5.23 Effects of storage temperature on CI of 'Buoi' mangoes after removal from cold storage and ripening for 4 days.

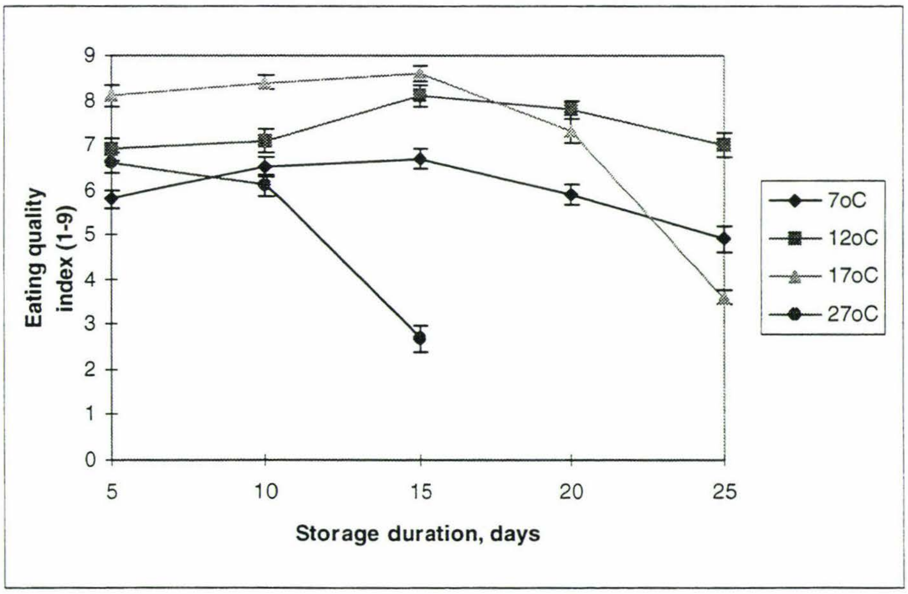

Figure 5.24 Effects of storage temperature on EQ of 'Buoi' mangoes after removal from cold storage and ripening for 4 days.

5.5 Discussion

The results show that postharvest quality attributes of 'Buoi' mangoes were significantly affected by storage temperature and time. Fruit weight loss increased with increase in storage time; however, at higher storage temperature fruit lost more weight (Figure 5.1). This result was similar to the result reported by Veloz et al. (1977) on 'Kent' mangoes and Vazquez-Salinas and Lakshminarayana (1985) on 'Haden', 'Irwin', 'Kent' and 'Keitt'.

During storage at different temperatures 'Buoi' mangoes significantly ($P < 0.05$) reduced the green colour and increased the yellow colour (Figure 5.3), but the yellow colouration process occurred faster in fruit stored at higher temperature. O'Hare (1995) found chlorophyll loss in 'Kensington' mangoes stored at 30°C was higher and caroteinoid synthesis lower than in those stored at 13°C. Medlicott et al. (1986) explained peel colour changes during ripening appeared to result from both chlorophyll loss and carotenoid increase. Similar to the peel colour, the pulp colour of 'Buoi' mangoes significantly ($P < 0.05$) changed from white to yellow-orange with increase in storage temperature or/and in storage time (Figure 5.4). Vazquez-Salinas and Lakshminarayana (1985) reported similar result that caroteinoids which causes yellow colour development (Cua, 1989; Medlicott, 1985) increased with increase in storage temperature.

The results on firmness was similar to the result reported by Abu-Sarra and Abu-Goukh (1992) and Thompson (1971). Abu-Sarra and Abu-Goukh (1992) reported that mango fruit declined firmness during storage. The authors explained that the loss of firmness during ripening of mango fruit may be resulted by an increase in PE activity, a decrease in PG and in cellulose activity. Thompson (1971) indicated that 'Julie' mangoes reduced firmness with increase in storage temperature.

Up to 20 days of storage at 7, 12, and 17°C soluble solids content in 'Buoi' mangoes increased with increase in storage time, but after that slightly declined. While this maximum point in fruit stored at ambient temperature was 10 days (Figure 5.13). This result was similar to the results reported by Krishnamurthy and Subramanyana (1973) on 'Alphonso' mangoes. In the period from 5 to 10 days storage, increasing storage temperature led to increase SSC, but after that this was correct only when temperature was increased up to 17°C. SSC reduced if continued to increase temperature higher. Fruit stored at 17°C for 20 days had the highest SSC. Vazquez-Salinas and Lakshminarayana (1985) also showed the SSC in ' Haden' mangoes was the highest (15.7%) when fruit stored at 18°C. The change of total acidity in 'Buoi' mangoes when increased storage temperature and storage time was similar to the change in 'Haden', 'Irwin', 'Kent' and 'Keitt' reported by Vazquez-Salinas and Lakshminarayana (1985) and in 'Alphonso' reported by Krishnamurthy and Subramanyana (1973).

'Buoi' mangoes fruit severed apparent chilling injury after 20 days stored at 7°C and 25 days stored at 12°C. Lowering storage temperature or storage time led to increase chilling injury. This result is similar to the result reported by Chaplin et al. (1991) on 'Kensington' mangoes. However, 'Kensington' mangoes can be stored at 10°C up to 4 weeks without chilling injury, while 'Buoi' mangoes severed chilling injury when stored at 12°C for only 25 days. This characteristic of 'Buoi' mangoes is similar to most of the mangoes grown in tropical countries which recommended by Hatton et al. (1965) and Thompson (1971) not to be stored below 13°C.

After 4 days ripening at 25°C, SSC, chilling injury and eating quality were higher than at the time of removal from cold storage, but acidity was lower. This result was similar to the result reported by Chaplin et al. (1991) on 'Kensington' mangoes , 'Buoi' mangoes suffered serious chilling injury after ripening.

Regression models were developed for predicting the postharvest quality attributes of 'Buoi' mangoes as a function of storage temperature and storage time. In all models the coefficients of determination were are very high (Table 1 to 9). However, 'Buoi' mangoes stored at ambient temperature were destroyed if stored longer than 15 days, so that the data for fruit stored at 27°C for 20 and 25 could not be collected . This limits the application of the prediction models to temperature $7 \leq x \leq 17$°C during 25 days storage. The models for weight loss (Figure 5.2), peel (Figure 5.7) and pulp colour (Figure 5.8), firmness (Figure 5.11), and total acidity (Figure 5.16) are not affected too much, however, the models for SSC (Figure 5.14) and eating quality (Figure 5.20) are affected. The results and discussion show that SSC and eating quality of 'Buoi' mangoes increased during storage temperature and declined after reaching a maximum.

4.6 Conclusions

The postharvest quality attributes of 'Buoi' mangoes were affected by storage temperature and storage time. In all storage temperature treatments increasing storage time led to increase in weight loss, peel and pulp colour, but declined in flesh firmness and crushing stress, and total acidity and chilling injury. At storage temperatures of 7, 12, and 17°C soluble solids content and eating quality increased up to around 20 days, and declined after that, while at ambient temperature this critical time was 10 days.

Storage temperature was an important factor affecting postharvest quality attributes of 'Buoi' mangoes. Increasing storage temperature led to increase in weight loss rate, yellow development in peel and pulp colour, but decline in flesh firmness, crushing stress, total acidity and chilling injury. Soluble solids content and eating quality increased with increase in storage temperature to maximum points and declined afterwards.

After ripening SSC was higher in fruit stored at 17°C or 12°C compared to stored at 7°C or 27°C. Similar to fruit removed from cold storage, ripened fruit stored at 7 and 12°C were affected by CI but the incidence was higher in ripened fruit.

Theses results showed that 'Buoi' mangoes can be stored at 12°C up to 20 days without serious chilling incidence and with acceptable postharvest quality attributes. Fruit stored at 17°C gave better quality than at 12°C if stored up to 15 days. Therefore, 'Buoi' mangoes can be stored at 12°C for long term storage, especially during long-distance marketing, and 17°C for short-term refrigeration storage. The regression models of postharvest quality attributes of 'Buoi' mangoes can be used for predicting fruit stored at temperature from 7°C to 27°C up 15 days and from 7°C to 17°C up to 25 days.

CHAPTER 6

EFFECTS OF POSTHARVEST TREATMENTS ON QUALITY ATTRIBUTES OF 'BUOI' MANGOES

6.1 Introduction

The presence of postharvest diseases and disorders such as anthracnose lesions and stem-end rot (Figure 6.1) have been known to cause major quality and quarantine problems in the mango export trade in over the world (Johnson et al., 1990; McIntyre et al., 1993). Mango anthracnose caused by *Colletotrichum gloeosporioides* Penz. (Dodd et al., 1997; Pelser and Lesar, 1989) is the most common cause decay of mango fruits in Vietnam (Minh et al., 1993). Anthracnose occurs pre- and postharvest and is associated with high rainfall and humidity (Dodd et al., 1992; Fitzell and Peak, 1984; Jeffries et al., 1990).

Figure 6.1 'Buoi' mangoes affected by anthracnose (2 fruits top left), stem-end rot (2 fruits bottom) and healthy fruit (2 fruit top right).

Postharvest hot water treatment is now accepted worldwide to satisfy quarantine requirements for control of anthracnose in mango (McIntyre et al., 1993; Sharp, 1988; Spalding et al., 1988; Suhardjo et al., 1994). For hot water treatment, at different dipping conditions have been recommended to control anthracnose effectively, but a general conclusion is that the water temperature should be between 50 and 55°C and dipping time must be at least 5 min (Dodd et al., 1997). The use of hot benomyl dips appears to be the most effective means of controlling anthracnose development (Dodd et al., 1991). However, there is worldwide concern on the use of agrichemical in relation to product safety.

Stem-end rot in mango is the other disease which is more specific and difficult to control (Huang and Liu, 1995). Dipping fruit in hot water at 55°C for 5 min gave good control of stem-end rot of mango cv. Nam Dorkmai and without heat injury (Sangchote, 1989). Immersion in hot water (52°C for 5 min) plus benomyl has also been reported to reduce stem-end rot on mangoes (Johnson et al., 1990).

Chilling injury is the most serious disadvantage of refrigeration in extending the storage life of mangoes (Veloz et al., 1977). McCollum et al. (1993) showed that heat treatment can inhibit chilling injury of mango. The authors reported that 'Keitt' mango were kept at 38°C for 0, 24, or 48 hours before storage at 5°C for 11 days and nonheated fruit developed severe rind pitting and discoloration, whereas chilling injury symptoms decreased with increased duration at 38°C.

The objective of this study was to determine the effect of postharvest hot water treatment on postharvest quality attributes such as weight loss, peel and pulp colour, SSC, the development of anthracnose, stem-end rot, shrivel and chilling injury in 'Buoi' mangoes harvested at different times during storage at 12°C (RH 85-90%).

6.2 Experimental Design

Mature, green 'Buoi' mangoes were harvested at three different times as described in Chapter 4 in Tien Giang Province, Vietnam and transferred to laboratory in Hochiminh City.

On each date, a sample of 40 fruits without disease and physical injury were randomly selected and divided into four sub-samples (ten in each sub-sample). The fruit samples were then randomly assigned to the following treatments and put in cold storage at 12 ± 1°C (RH 85-90%): treatment 1 = fruit dipped in hot water at 52°C for 5 min; treatment 2 = fruit dipped in hot water at 52°C for min; treatment 3 = fruit placed in PVC plastic bag; and treatment 4 = control (untreated) fruit. After 24 days storage, fruit were removed from cold storage and assessed for weight loss, peel and pulp colour, soluble solids content, anthracnose, stem-end rot, shrivel and chilling injury as discussed in Chapter 3.

6.3 Data Analysis

Data on weight loss, peel and pulp colour, soluble solids content, anthracnose, stem-end rot, shrivel and chilling injury were subjected to analysis of variance, and the treatment means were compared using least significant difference (SAS, 1996).

6.4 Results

Skin and pulp colour

Both hot water treatments significantly ($P < 0.05$) increased the rate of peel and pulp colour development compared to plastic bag and the control. However, there was no significant difference in peel and pulp colour of fruit dipped in hot water for 5 or 10 min. (Table 6.1). Fruit stored in plastic bag had the lowest rate of skin and pulp colour development. The harvest date did not affect the colour development of both treated and untreated fruit.

Soluble solids content (SSC)

Soluble solids content of hot water treated fruit were significantly ($P < 0.05$) higher compared to control fruit and fruit in plastic bag (Table 6.1). And similar to their effects on colour development, there was no significant difference between SSC of fruit dipped in hot water at 52°C for 5 min or 10 min. Fruit in plastic bag had the lowest SSC.

Weight loss

Putting fruit in plastic bag depressed the rate of weight loss ($P < 0.05$) compared to other treatments. Maximum weight loss occurred in fruit treated with hot water at 52°C for 10 min, and there was no significant difference in the weight loss of control fruit and fruit treated with hot water treatment at 52°C for 5 min. Early harvested fruit lost more weight than late harvested fruit (Table 6.1).

Shrivel

Fruit treated with hot water at 52°C for 10 min had the highest shrivelling incidence, while fruit in plastic bag or treated with hot water at 52°C for 5 min had the lowest shrivel incidence (Table 6.1).

Anthracnose

Figure 6.2 shows the effect of postharvest treatments on anthracnose development of 'Buoi' mango fruit. Hot water treatments at 52°C (for 5 or 10 min) significantly decreased anthracnose disease compared with fruit in plastic bag and untreated fruit. Fruit picked at the first harvest had highest anthracnose disease, especially in plastic bag and control fruit.

Table 6.1. Effect of postharvest treatments and harvest date on postharvest quality attributes of 'Buoi' mangoes after storage at 12 ± 1°C for 24 days.

Postharvest treatments	Fruit quality attributes				
	peel colour	pulp colour	SSC, (%)	Weight loss, (%)	Shrivel
Harvest I					
Control	3.6b*	3.9b	13.5b	8.6b	0.3b
Plastic bag	2.8c	3.4c	12.9c	6.52c	0.1c
Hot water, 52°C, 5 min	4.0ba	4.2ab	14.4a	8.42b	0.2bc
Hot water, 52°C, 10 min	4.3a	4.5a	14.5a	9.56a	0.6a
Harvest II					
Control	3.6b	3.8bc	13.7b	8.14b	0.2b
plastic bag	2.9c	3.4c	13.1c	6.32c	0.0c
Hot water, 52°C, 5 min	4.1a	4.2ab	14.5a	8.23b	0.2b
Hot water, 52°C, 10 min	4.4a	4.5a	14.6a	9.38a	0.6a
Harvest III					
Control	3.7b	3.9b	13.8b	7.78b	0.2b
Plastic bag	2.8c	3.5c	13.3c	6.27c	0.1b
Hot water, 52°C, 5 min	4.1ab	4.4a	14.7a	7.83b	0.2b
Hot water, 52°C, 10 min	4.5a	4.6a	14.6a	9.34a	0.5a

*Means in a column with the same letter are not significantly different ($P < 0.05$) for each harvest date.

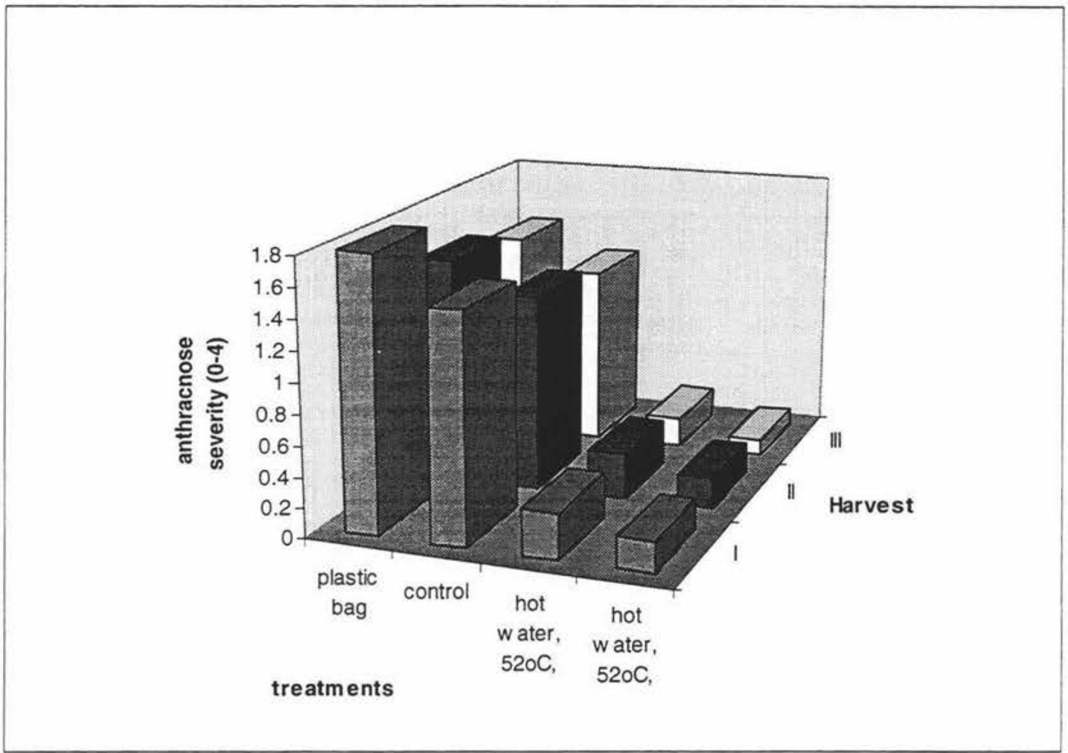

Figure 6.2 Effects of postharvest treatments and harvest date on anthracnose in 'Buoi' mangoes (I = 10/3/97; II = 24/3/97; III = 7/4/97).

Stem-end rot

Hot water treatment at 52°C for 5 or 10 min gave good control of stem-end rot compared to the nontreated (control) fruit and fruit in plastic bag (Figure 6.3). Dipping fruit in water at 52°C for 10 min controlled stem-end rot better than dipping time for only 5 min. Stem-end rot incidence was lower in late harvested fruit.

Chilling injury

There were no evidence of chilling injury in fruit dipped in hot water at 52°C for 5 or 10 min, but the fruit in plastic bag or control were affected (Figure 6.4). Control fruit were mostly affected by chilling injury, and fruit picked at the first harvest were more sensitive to chilling injury than those harvested later.

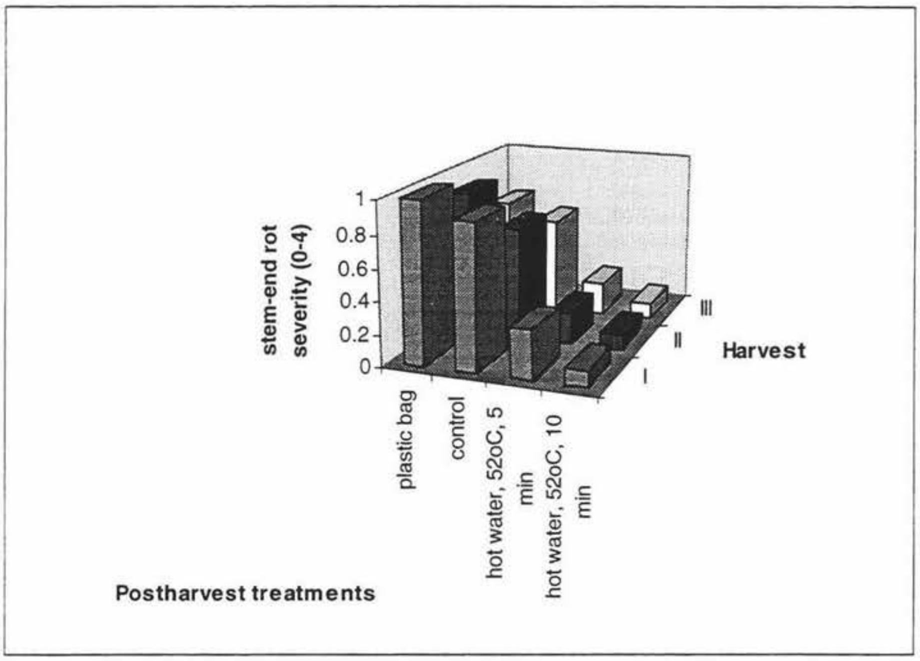

Figure 6.3 Effects of postharvest treatments and harvest date on stem-end rot in 'Buoi' mangoes (I = 10/3/97; II = 24/3/97; III = 7/4/97).

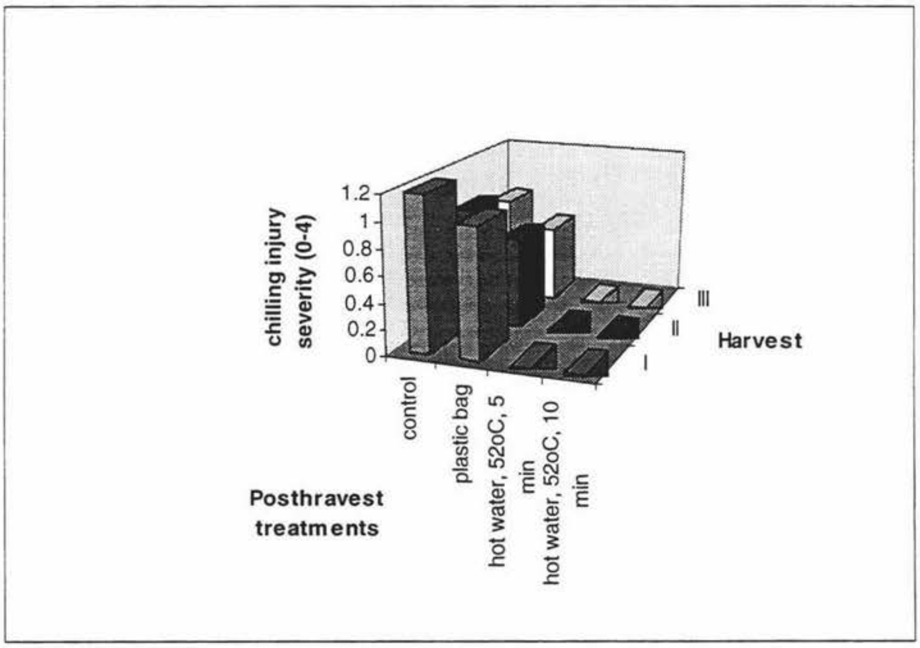

Figure 6.4 Effects of postharvest treatments and harvest date on chilling injury in 'Buoi' mangoes(I = 10/3/97; II = 24/3/97; III = 7/4/97).

6.4 Discussion

Fruit weight loss and rate of yellow colour development in plastic bag were significantly ($P < 0.05$) lower compared to hot water treatments or controls, presumably due to higher relative humidity inside the plastic bags. High relative humidity may also contribute to the high incidence of postharvest diseases such as anthracnose and stem-end rot in fruit stored in plastic bags.

Hot water treatment at 52°C for 5 or 10 min gave good control of diseases, anthracnose, and stem-end rot of 'Buoi' mango compared to plastic bag and controls ($P < 0.05$). Disease control increased with increased dipping time (mango fruit in hot water at 52°C for 10 min showed a better control of anthracnose and stem-end rot than for 5 min) (Figure 6.2). However, increasing the dipping time can lead to increase in weight loss and shrivelling incidence (Table 6.1). These results are similar to those reported by Sangchote (1989) on 'Nam Dorkmai' mangoes. The author indicated that disease control increased with increased temperature and dipping time.

The peel and pulp colour, SSC, and weight loss of 'Buoi' mango fruit dipped in hot water (52°C for 5 or 10 min) increased significantly ($P < 0.05$) compared with fruit in plastic bag and controls. On the other hand, these quality attributes of fruit dipped in hot water at 52°C for 5 and 10 min were not significantly ($P < 0.05$) different. The fruit in plastic bag had the lowest weight loss rate and shrivel incidence, but they were more susceptible to anthracnose and stem-end rot than hot water treated fruit.

There was no evidence of chilling injury on fruit dipped in hot water at 52°C for 5 or 10 min after 24 days storage at 12°C, while fruit in plastic bag and especially untreated fruit were affected by chilling injury (Figure 6.4). This result indicates that hot water treatment at 52°C for 5 or 10 min can inhibit chilling injury in 'Buoi' mango as reported by McCollum et al. (1993) with heat treatment on 'Keitt' mangoes.

Similar to the results presented in Chapter 4 the harvest date did not significantly ($P < 0.05$) affect the postharvest quality attributes such as peel colour, pulp colour, soluble solids content, and shrivel , but affected weight loss, incidence of diseases and chilling injury. Fruit picked during early season harvest had higher weight loss rate and were more susceptible to anthracnose, stem-end rot and chilling injury. Higher incidence of chilling injury in early harvested mango fruit 'Tommy Atkins' has been reported by Medlicott et al. (1990).

6.5 Conclusions

'Buoi' mangoes treated with hot water treatment at 52°C for 5 or 10 min significantly reduced the incidence of anthracnose and stem-end rot disease and also chilling injury compared to fruit in plastic bag or untreated fruit. Fruit in plastic bag lost less weight than in the other treatments. Despite 'Buoi' mangoes treated with hot water at 52°C for 10 min gave better control anthracnose and stem-end rot , hot water at 52°C for 5 min is recommended for postharvest hot water treatment because this method can reduce the weight loss and shrivelling which are very important for marketing.

Harvest date did affect the development of postharvest diseases such as anthracnose and stem-end rot and chilling injury. Early harvested lost more weight and were more susceptible to anthracnose, stem-end rot and chilling injury than mid- and late harvested fruit. Therefore, for long distance markets and for export 'Buoi' mangoes must be harvested in mid- or late season to minimise the development of postharvest diseases and disorder.

CHAPTER 7

GENERAL DISCUSSION AND CONCLUSIONS

7.1 Introduction

The primary aim of this thesis was to investigate the effects of harvest date and storage temperature on postharvest quality attributes of 'Buoi' mangoes grown in Vietnam. The effects of the postharvest treatments such as hot water and plastic bag packaging on postharvest quality attributes and incidence of disease and disorder such as anthracnose, stem-end rot and chilling injury were also determined. An extensive review on postharvest handling and storage of mango was conducted. In addition, regression models for predicting postharvest quality attributes of 'Buoi' mangoes such as weight loss, peel and pulp colour, texture, SSC, total acidity, chilling injury, and eating quality as a function of storage temperature and time were developed. Detailed discussion of the results have been presented the relevant chapters.

The objective of the present Chapter is to provide a general discussion of these results and identify further opportunities for research to reduce postharvest losses and maintain the postharvest quality of 'Buoi' mangoes.

7.2 General Discussion and Conclusions

7.2.1 General Discussion

Harvest date significantly affected some of postharvest quality attributes of 'Buoi' mangoes such as weight loss and texture, but does not affect the other attributes such as peel and pulp colour, soluble solid content, total acidity and eating quality. In addition, the harvest date also influenced the development postharvest diseases such as anthracnose and stem-end rot and chilling injury, a storage disorder.

The results in Chapter 4 and 6 show that during storage at 12°C (RH 85-90%), the fruit harvested at early season (both fruit treated hot treatments or untreated) lost more weight compared with mid- and late harvested fruit (Figure 4.1 and Table 6.1). Weight loss as described by Wills et al. (1989) is loss of saleable weight and it cause many perishable commodities to appear wilted and shrivelled. Thompson (1971) showed that shrivelling in 'Julie' mangoes reduced with increase maturity stage. The results on 'Buoi' mangoes in Table 6.1 show similar with the result reported by Thompson (1971). During storage at 12°C, in case control (untreated) fruit, shrivelling in early harvested fruit was higher in mid- and late harvested fruit. However, in treated fruit (with hot water treatments or in plastic bag) the shrivelling incidence was not different between harvests. This result maybe related to the weight loss. Because the results in Table 6.1 show that in control fruit the weight loss rate in early harvested fruit was significantly higher than in mid- and late harvested fruit, while these values in treated fruit were not so different.

Storage duration up to 10 days, the texture of the mid- and late harvested fruit was lower than early harvested fruit. However, if increased storage duration longer, this difference disappeared. Soluble solids content (SSC) was reported to be correlated with texture (Seymour et al., 1990). In immature fruit firmness was higher, but lower in SSC than in half mature and mature fruit . Appendix 2 (Table2.3) shows that SSC in early harvested 'Buoi' mangoes was significantly higher than in mid- and late harvested fruit up to 10 days storage, later there was no difference in SSC between harvests.

After 4 ripening at 25°C the postharvest quality attributes such as SSC, total acidity, chilling injury and eating quality seem to be not affected by harvest date (see Chapter 4). However, the result of SSC is different with the result reported by Medlicott et al. (1990) on 'Keitt' mangoes. The authors showed that SSC in half mature and mature fruit had higher than in immature fruit.

Chilling injury is a storage disorder found to be affected by harvest date. (See Chapter 4 and 6). Early harvested 'Buoi' mangoes suffered more serious chilling injury than mid- and late harvested fruit. This result was similar to the results reported by Medlicott et al. (1990) on 'Amelie' mangoes. Pantastico et al. (1975), Saltveit et al. (1990), and Weis et al. (1993) also concluded that ripe fruit are more resistant to chilling injury than unripe fruit.

The results in Chapter 4 and 5 show that storage temperature and length of storage are two very important factors affecting postharvest quality attributes of 'Buoi' mangoes. Similar to the result reported by Krishnamurthy and Subramanyam (1973) on 'Alphonso' the weight loss rate increased with increase storage duration, particularly in high storage temperatures such as 17°C or 27°C (Figure 4.1 and 5.1). During storage, there was a significant increase in peel and pulp yellowiness of 'Buoi' mangoes (Figure 4.2 and 4.3). This change in peel and pulp colour is explained to be associated with a loss of chlorophyll and an increase in carotenoids (Cua, 1989; Medlicott, 1985; Medlicott et al., 1986). Increasing storage temperature also lead to significantly change in the colour of fruit peel and pulp (Figure 5.3 and 5.4). Kader (1992) and Wills et al. (1989) showed that increase in storage temperature is associated with increase in respiration rate which is an important factor accelerating ripening process in the fresh commodity.

Fruit texture (firmness and crushing stress) of 'Buoi' mangoes declined with increase storage duration (Figure 4.4 and 4.5) or storage temperature (Figure 5.9 and 5.10). This result is similar to the result reported by Abu-Sarra and Abu-Goukh (1992) and Thompson (1971). Softening of mango fruit was reported to be resulted by an increase in PE activity, a decrease in PG and in cellulose activity (Abu-Sarra and Abu-Goukh, 1992; Lazan et al., 1986; Medlicott, 1985).

Soluble solids content in 'Buoi' mangoes during storage at different temperatures was similar to the result reported by Krishnamurthy and Subramanyana (1973) on ' Alphonso' mangoes. Increasing storage duration, at first led to increase in SSC to maximum point and declined after that. The time reached to that maximum point was different with different storage temperature. Soluble solids content in 'Buoi' mangoes stored at 17°C for 20 days was highest (12.9%) if compared to SSC in fruit stored at 7, 12°C or ambient temperature. Vazquez-Salinas and Lakshminarayana (1985) also reported that the SSC in 'Haden' mangoes was the highest (15.7%) when fruit stored at 18°C. The change of total acidity in 'Buoi' mangoes when increased storage temperature and storage time was similar to the change in 'Haden', 'Irwin', 'Kent' and Keitt' (Vazquez-Salinas and Lakshminarayana, 1985) and in 'Alphonso' (Krishnamurthy and Subramanyana, 1973). Total acidity reduced with increase in storage temperature or /and storage time.

Similar to the other mango cultivars 'Buoi' mangoes suffered chilling injury more serious when increased storage time or/and lowered storage temperature. However, if compared with 'Kensington' mangoes, 'Buoi' mangoes are more susceptible to chilling injury. 'Buoi' mangoes severed chilling injury when stored at 12°C for 25 days while Chaplin et al. (1991) showed that 'Kensington' mangoes stored at 10°C up to 4 weeks without this incidence. Eating quality is an important quality that consumers decide whether fruit still good or not. This quality parameter depends on the other quality attributes such as firmness, sugar and flavour. Similar to SSC, eating quality of 'Buoi' mangoes was the best when fruit stored at 17°C for 20 days.

Regression models were developed for predicting postharvest quality attributes of 'Buoi' mangoes as a function of storage temperature and storage time (Figure 5.2, 5.7, 5.8, 5.11, 5.12, 5.14, 5.16, 5.18 and 5.20). These models can help growers to know how long the commodity can be stored at specific storage temperature with acceptable quality. Although, the regression coefficients were high in all the models, there are still some disadvantages as discussed in Chapter 5.

7.2.2 General Conclusions

Most of the postharvest quality attributes of 'Buoi' mangoes were affected by storage temperature and storage time, while only some of these found depending on harvest date. Increasing storage temperature or/and storage time led to increase in weight loss, peel and pulp colour, but declined in fruit texture (flesh firmness and crushing stress) and total acidity. Increasing storage time or/and lowering storage temperature resulted to increase susceptible to chilling injury. Fruit stored at 12°C were severed serious chilling injury after 25 days storage, while fruit stored at 7°C severed serious incidence only after 15 days. There was no evidence of chilling injury in the fruit stored at 17°C and 27°C after 25 days. Soluble solids content and eating quality increased with increase storage duration first, but after that they declined. This critical point was dependent on fruit stored at specific storage temperature.

According to findings in previous chapters 'Buoi' mangoes stored at 12°C up to 20 days without serious chilling injury and with acceptable postharvest quality attributes, thereby is recommended for long term cold storage, for example for export or long distance markets. Fruit stored at 17°C gave better quality than at 12°C if storage up to 15 days, therefore, 'Buoi' mangoes are recommended to be stored at 17°C for shorter marketing. They are not recommended to be stored at 7°C or at ambient temperature (27°C). The regression models of postharvest quality attributes of 'Buoi' mangoes as a function of storage temperature and storage time are suitable for predicting fruit stored at temperature from 7°C to 27°C up to 15 days and from 7 to 17°C up to 25 days .

Harvest date was found to influence some postharvest quality attributes of 'Buoi' mangoes as well as postharvest diseases such as anthracnose and stem-end rot and storage disorder such as chilling injury. During storage at 12°C (RH 85-90%) the early harvested fruit lost more weight compared to the mid- and late harvested fruit. There was no significantly difference in weight loss between mid- and late harvested fruit. The harvest date significantly affected fruit texture only in the first 10 days storage. Chilling injury, and anthracnose and stem-end rot disease were affected by harvest date. Early harvested fruit suffered more chilling incidence, anthracnose and stem-end rot compared to mid- and late harvested fruit. Because of the effects of harvest date on some of fruit quality and postharvest diseases and disorders, 'Buoi' mangoes harvested for long term cold storage should harvested in the mid- or late season if there is no postharvest treatment applications.

'Buoi' mangoes treated with hot water at 52°C for 5 or 10 min significantly reduced the incidence of anthracnose, stem-end rot, as well as chilling injury compared to fruit in plastic bag or control (untreated) fruit. After 24 days storage at 12°C, there was no evidence of chilling injury in hot water treated fruit, while it already appeared serious in control fruit and fruit in plastic bag. Although hot water treatment at 52°C for 10 min gave better control anthracnose and stem-end rot , hot water at 52°C for 5 min is recommended to be applied because this method gave better postharvest quality attributes.

7.3 Recommendations for Further Research

The studies reported in this thesis have provided a greater understanding of postharvest quality attributes of 'Buoi' mangoes grown in Vietnam as affected by postharvest factors such as harvest date, storage duration, storage temperature. However, after these studies also have developed some questions which need further research. Based on the overall results obtained in this study, the following areas of further research are suggested:

Maturity assessment of 'Buoi' mango

The effects of harvest date on postharvest quality attributes of 'Buoi' mangoes have been discussed in Chapter 4. However, we still do not know the relation between harvest date and stage of maturity of 'Buoi' mangoes. Further study is required to determine the relationship between harvest date and stage of maturity of 'Buoi' mangoes. This should include the determination of appropriate indices for assessing the maturity of fruit.

Modelling fruit quality

Regression models for predicting the postharvest quality attributes of 'Buoi' mangoes as function of storage temperature and storage time were developed in Chapter 5. The application of the regression models developed for predicting mango fruit quality are limited to the range of temperatures tested (7 - 27°C). The accuracy and application of these could be improved by increasing the number of temperature intervals, for example 6, 10, 14, 18, 22, 26°C. The results of such studying will also facilitate the determination of the optimum cold storage requirements for 'Buoi' mangoes.

Hot water treatment

Both finance and time limitations precluded the inclusion of other hot water treatments and the use of Benomyl (Johnson et al., 1990) in determining the best postharvest of 'Buoi' mangoes to reduce the incidence of diseases and disorders. It is recommended that both the range of temperatures and dipping times be increased, with and without benomyl, to determine the optimum hot water treatment for 'Buoi' mangoes.

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APPENDIX 1

Table 1.1 Effects of harvest date on weight loss rate (%) of 'Buoi' mangoes during storage at 12°C (RH 85-90%)

No	Harvest I					Harvest II					Harvest III				
	5 d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d
1	1.68	2.75	5.23	7.80	9.62	1.26	2.12.	4.31	7.33	8.56	1.44	2.38	4.74	6.59	8.48
2	1.84	2.85	5.18	7.48.	8.84	1.50	2.49	4.00	6.94	8.87	1.44	2.19	3.89	6.78	8.71
3	1.77	2.94	5.20	8.24	9.91	1.43	2.81	3.98	7.53	8.72	1.59	2.60	4.57	6.89	9.08
4	1.93	3.21	4.80	7.25	9.92	1.45	2.72	4.14	7.32	9.43	1.24	2.31	4.39	7.37	8.92
5	1.50	2.61	4.85.	8.35	10.01	1.27	2.36	4.26	7.87	9.15	1.53	2.29	3.81	6.99	8.40
6	1.48.	2.71	5.09	8.27	9.95	1.44	2.52	4.46	6.96	8.69	1.37	2.25	4.72	6.78	8.44
7	1.69	2.78	5.16	7.85	9.42	1.55	2.70	5.02	7.11	9.30	1.45	2.12	3.86	7.14	8.95
8	1.89	2.71	4.97	7.51	8.79	1.51	2.55	4.36	6.97	8.96	1.32	2.35	3.81	7.31	8.16
9	1.71	2.72	5.40	8.04	9.31	1.52	2.50	4.43	6.73	8.65	1.35	2.47	3.85	7.19	9.40
10	1.87	2.78	4.88	8.63	9.57	1.39	2.07	4.22	6.72	9.05	1.26	2.35	4.04	7.46	8.90
11	1.64	3.08	5.22	8.19	9.05	1.37	2.30	4.43	6.99	9.21	1.34	2.56	4.49	7.47	9.35
12	1.65	3.41	5.13	7.51	8.56	1.45	2.56	4.37	7.85	9.10	1.27	2.45	4.01	7.03	8.48
13	1.66	2.82	4.48	7.35	9.15	1.58	2.56	4.29	7.63	8.78	1.49	2.50	4.54	6.94	9.04
14	1.90	2.56	5.18	8.78	9.88	1.37	2.54	4.24	7.03	8.89	1.44	2.49	4.31	7.66	9.00
15	1.69	3.13	5.25	7.02	8.99	1.46	2.22	4.24	7.43	8.96	1.43	2.62	4.10	7.05	8.26
16	1.86	2.74	4.39	7.22	9.17	1.27	2.47	4.59	7.74	8.74	1.45	2.17	4.73	6.62	8.88
17	1.60	2.83	5.45.	8.65	10.39	1.25	2.23	4.26	6.85	8.74	1.29	1.96	4.40	6.80	9.20
18	1.52	2.63	4.63	8.10	9.29	1.60	2.49	5.10	7.30	8.51	1.30	2.32	4.33	6.86	7.66
19	1.74	3.18	5.50	6.79.	9.53	1.58	2.38	4.24	7.67	8.52	1.46	2.10	3.85	6.96	8.75
20	1.47	3.11	5.16	7.40	9.68	1.26	2.30	4.47	7.41	9.09	1.30	2.67	3.97	6.68	8.39

Table 1.2 Effects of harvest date on colour of 'Buoi' mangoes during storage at 12°C (RH 85-90%)

PEEL COLOUR index

No	Harvest I						Harvest II						Harvest III					
	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d
1	2	3	3	3	4	4	2	2	2	3	3	3	2	2	3	3	3	4
2	2	2	2	3	3	4	2	2	3	3	3	3	2	3	2	3	3	3
3	2	2	2	3	3	4	2	2	2	2	2	3	2	2	2	3	3	3
4	2	2	2	2	3	4	2	2	2	2	3	3	2	2	3	4	4	4
5	2	2	2	2	3	4	2	2	2	2	3	2	2	2	2	3	3	3
6	2	2	3	2	3	4	1	2	2	2	2	3	2	2	3	3	3	5
7	1	2	2	3	3	4	2	2	2	3	3	3	2	2	4	3	3	4
8	2	2	3	2	4	3	1	2	2	3	3	3	2	2	2	3	4	3
9	2	2	2	4	3	3	2	2	2	2	3	4	1	3	3	2	4	5
10	2	2	3	3	3	3	2	2	3	3	3	3	2	2	3	3	3	3

PULP COLOUR index

No	Harvest I						Harvest II						Harvest III					
	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d
1	2	3	3	3	4	4	2	2	3	3	4	4	2	2	3	3	3	5
2	2	2	3	3	4	3	2	3	2	3	3	4	2	3	2	3	3	3
3	2	2	3	3	3	4	2	2	3	3	4	4	2	2	2	3	4	3
4	2	2	2	2	3	3	2	2	3	3	3	4	2	2	3	4	4	4
5	2	2	2	3	3	4	2	2	3	3	3	3	2	2	2	3	3	3
6	2	3	3	2	4	4	2	2	2	3	4	4	2	3	3	3	3	4
7	2	2	3	3	3	4	1	2	3	3	3	4	2	2	4	3	3	4
8	2	2	2	2	4	3	2	2	2	3	3	4	2	2	2	4	4	3
9	2	3	3	4	2	4	2	2	3	3	3	3	1	2	2	2	4	5
10	2	2	2	4	3	3	2	3	3	3	4	3	2	2	3	3	3	3

Table 1.3 Effects of harvest date on texture of 'Buoi' mangoes during storage at 12°C (RH 85-90%)

FIRMNESS, N

No	Harvest I						Harvest II						Harvest III					
	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d
1	70	62	55	42	40	39	64	60	53	45	42	38	61	56	54	45	37	38
2	65	59	50	40	38	44	62	53	54	46	40	36	67	57	51	46	40	36
3	63	57	54	50	41	41	65	54	51	42	38	42	60	57	48	41	38	42
4	70	59	52	47	45	36	67	61	51	48	44	38	63	56	52	48	39	38
5	70	61	55	48	42	39	64	57	54	46	36	39	61	59	50	46	38	39
6	65	59	53	44	44	35	68	57	49	42	43	40	64	54	49	42	43	35
7	64	55	54	46	40	38	60	56	50	42	41	35	66	59	55	45	45	35
8	65	59	53	42	41	42	61	53	57	45	39	36	62	53	47	42	39	36
9	64	62	53	44	42	37	60	56	51	43	44	35	64	57	49	45	44	35
10	65	57	52	45	45	36	63	55	48	42	40	37	63	53	50	45	40	36

CRUSHING STRESS, kPa

No	Harvest I						Harvest II						Harvest III					
	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d
1	2743	2313	1770	641	349	354	2590	2242	1456	749	343	343	2420	2060	1365	488	383	304
2	2482	2571	1730	567	355	271	2556	1836	1805	799	298	330	2360	2176	1481	864	343	343
3	2736	2625	1515	782	391	279	2222	1945	1353	680	334	264	2562	1801	1613	641	384	327
4	2894	2344	1537	686	262	385	2574	2373	1799	680	403	264	2256	2048	1470	467	310	264
5	3216	2354	1748	659	271	299	2681	2151	1353	790	318	304	2845	1813	1468	617	334	317
6	2936	2694	1574	682	359	277	2508	2166	1688	690	384	327	2357	2000	1782	723	478	314
7	2555	2182	1794	693	371	357	2416	2170	1561	716	310	332	2709	2088	1428	682	343	271
8	2624	2463	1750	723	319	340	2645	1920	1528	714	438	314	2451	2159	1597	659	310	277
9	3113	2453	1725	543	374	366	2697	2099	1578	680	478	287	2171	1795	1217	716	298	279
10	2594	2433	1643	617	333	357	2576	1989	1558	708	383	317	2357	2050	1580	708	384	357

Table 1.4 Effects of harvest date on SSC (%) of 'Buoi' mangoes during storage at 12°C (RH 85-90%)

No	Harvest I						Harvest II						Harvest III					
	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d
1	7.0	7.5	8.6	10.0	11.8	12.0	7.4	7.6	10.4	11.0	11.6	13.3	7.0	9.2	10.0	11.4	11.8	11.9
2	6.5	7.5	8.5	11.3	11.2	12.0	7.2	7.7	9.8	10.9	12.4	12.1	7.7	8.1	8.8	11.2	11.9	10.9
3	6.3	7.0	9.5	10.3	12.1	10.0	7.0	8.6	9.1	10.4	13.0	10.2	7.1	8.1	9.3	10.4	12.9	12.1
4	7.1	7.6	9.0	9.7	11.6	11.0	7.2	9.0	9.2	10.3	12.8	11.2	7.2	7.9	10.2	10.9	11.7	11.1
5	6.8	7.6	9.2	10.0	13.1	11.2	7.3	8.0	9.7	11.0	12.9	11.6	6.9	7.6	9.2	10.4	12.6	11.4
6	6.5	7.5	10.2	9.8	12.6	11.8	6.7	8.0	9.5	10.1	13.2	11.1	8.0	8.8	9.8	10.1	11.3	11.0
7	7.0	8.0	8.7	10.5	10.8	11.0	6.9	7.7	10.2	11.2	12.8	10.8	7.3	8.1	10.3	10.3	13.2	11.6
8	7.0	7.8	9.2	10.7	12.4	12.0	7.0	8.6	9.6	10.1	11.2	11.2	7.1	8.3	9.3	11.2	12.6	12.1
9	6.5	8.5	9.0	10.8	13.2	10.0	6.9	8.4	9.5	10.3	11.9	11.6	6.8	8.2	9.8	10.2	13.2	12.2
10	6.6	8.4	8.7	11.0	12.5	11.0	7.1	8.5	8.7	10.8	11.4	12.7	6.8	7.9	10.0	11.0	11.9	10.8

Table 1.5 Effects of harvest date on total acidity (%) of 'Buoi' mangoes during storage at 12°C (RH 85-90%)

No	HARVEST I						HARVEST II						HARVEST III					
	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d
1	1.34	0.98	0.97	0.79	0.59	0.54	1.28	0.90	0.91	0.72	0.66	0.63	1.26	1.06	0.82	0.68	0.63	0.47
2	1.26	1.00	0.92	0.82	0.63	0.52	1.36	1.05	0.92	0.70	0.59	0.55	1.23	0.96	0.96	0.73	0.67	0.52
3	1.22	1.08	0.85	0.70	0.67	0.50	1.23	1.03	0.80	0.69	0.67	0.57	1.32	1.02	0.85	0.77	0.57	0.56
4	1.40	1.09	0.98	0.90	0.64	0.56	1.29	0.92	0.92	0.79	0.66	0.54	1.35	1.03	0.85	0.69	0.64	0.60
5	1.20	0.99	0.92	0.79	0.65	0.55	1.34	1.03	0.89	0.68	0.59	0.60	1.29	0.93	0.93	0.81	0.58	0.54
6	1.27	0.93	0.85	0.88	0.59	0.60	1.24	0.93	0.76	0.73	0.65	0.52	1.32	0.92	0.86	0.75	0.68	0.58
7	1.30	1.07	0.97	0.75	0.72	0.48	1.22	1.00	0.89	0.71	0.61	0.62	1.25	1.01	0.83	0.79	0.62	0.55
8	1.20	0.96	0.82	0.97	0.65	0.65	1.33	0.97	0.79	0.81	0.59	0.56	1.30	1.06	0.92	0.72	0.59	0.48
9	1.47	1.09	0.87	0.81	0.70	0.58	1.27	0.94	0.78	0.78	0.62	0.54	1.28	1.03	0.88	0.78	0.62	0.49
10	1.44	1.00	0.92	0.74	0.75	0.64	1.31	1.01	0.91	0.72	0.57	0.61	1.33	0.95	0.84	0.74	0.58	0.53

Table 1.6 Effects of harvest date on chilling injury of 'Buoi' mangoes during storage at 12°C (RH 85-90%)

No	Harvest I			Harvest II			Harvest III	
	15d	20d	25d	15d	20d	25d	20d	25d
1	0	0	2	0	0	0	0	1
2	0	0	1	0	0	2	0	2
3	0	1	2	0	0	1	0	1
4	0	1	2	0	0	1	0	0
5	0	0	1	0	0	1	0	0
6	0	1	3	0	0	1	0	1
7	0	0	2	0	0	0	0	2
8	0	0	2	0	1	1	0	2
9	0	0	2	0	0	2	0	1
10	0	0	2	0	0	2	0	0

Table 1.7 Effects of harvest date on eating quality of 'Buoi' mangoes during storage at 12°C (RH 85-90%)

No	Harvest I						Harvest II						Harvest III					
	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d	0d	5d	10d	15d	20d	25d
1	2	3	3	6	8	7	1	3	4	6	8	7	2	3	3	6	8	7
2	3	3	5	5	7	6	2	3	3	5	7	8	2	3	5	5	7	6
3	2	3	4	5	6	7	2	3	5	5	8	6	2	2	4	5	6	7
4	2	3	3	7	7	6	2	2	4	5	8	6	2	3	4	7	8	6
5	2	3	4	6	8	6	2	3	3	6	7	6	2	3	4	6	8	6
6	1	2	4	6	7	7	2	3	4	5	7	7	1	2	4	6	7	6
7	2	2	3	5	8	6	2	3	3	6	6	6	2	2	3	5	8	6
8	2	4	3	5	6	8	2	2	4	6	8	6	2	4	3	5	6	8
9	2	3	4	5	8	7	2	3	4	5	7	6	2	3	4	5	8	7
10	2	2	4	5	8	6	1	3	3	5	7	7	2	2	4	5	8	6

Table 1.8 Effects of harvest date on SSC (%) of 'Buoi' mangoes during storage at 12°C and ripening at 25°C for 4 days.

No	Harvest I					Harvest II					Harvest III				
	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d
1	12.9	13.1	13.2	13.6	12.9	13.5	13.5	14.2	13.4	14.3	13.6	13.0	13.6	14.6	14.3
2	13.6	12.9	14.3	13.7	13.7	12.7	14.2	13.5	13.5	13.9	12.9	13.5	14.2	14.2	14.2
3	13.1	12.8	12.9	13.9	12.3	13.2	12.9	13.7	13.9	14.6	12.8	13.2	13.9	13.5	13.7
4	13.0	13.5	13.5	13.7	14.1	13.6	13.6	14.4	14.2	13.6	13.4	13.9	13.7	13.4	13.5
5	13.5	14.1	14.1	14.4	14.5	14.4	13.6	13.8	13.8	12.5	14.1	14.2	13.7	13.9	13.9
6	13.2	13.3	13.1	13.8	13.9	13.1	13.6	13.9	14.3	13.5	13.3	13.7	13.2	14.0	13.2
7	13.6	12.8	14.6	14.2	13.7	12.9	13.3	13.1	13.1	13.7	13.9	13.6	14.1	13.2	14.2
8	13.0	14.2	13.7	14.5	13.9	13.4	14.1	14.2	14.6	12.9	13.5	13.1	13.3	13.5	13.9
9	12.6	13.2	13.5	12.9	13.9	13.6	13.3	13.8	13.7	12.7	13.2	13.3	13.7	13.9	12.5
10	13.4	13.7	14.2	13.4	13.2	12.8	13.9	13.0	13.8	13.7	12.5	13.7	13.8	14.3	13.4

Table 1.9 Effects of harvest date on total acidity (%) of 'Buoi' mangoes during storage at 12°C and ripening at 25°C for 4 days.

No	HAVEST I					HAVEST II					HARVEST III				
	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d
1	0.35	0.29	0.33	0.31	0.36	0.29	0.42	0.29	0.33	0.25	0.27	0.40	0.30	0.37	0.37
2	0.35	0.39	0.31	0.28	0.32	0.44	0.39	0.33	0.31	0.34	0.42	0.39	0.33	0.32	0.29
3	0.31	0.35	0.29	0.29	0.67	0.35	0.41	0.31	0.36	0.31	0.43	0.30	0.29	0.34	0.30
4	0.40	0.39	0.31	0.41	0.25	0.41	0.28	0.33	0.28	0.37	0.29	0.26	0.28	0.28	0.26
5	0.42	0.42	0.37	0.22	0.21	0.34	0.39	0.34	0.23	0.59	0.43	0.41	0.37	0.36	0.24
6	0.30	0.37	0.27	0.34	0.31	0.27	0.29	0.26	0.33	0.29	0.30	0.40	0.31	0.38	0.30
7	0.42	0.31	0.38	0.31	0.31	0.43	0.32	0.39	0.35	0.31	0.44	0.29	0.26	0.30	0.36
8	0.42	0.44	0.35	0.30	0.26	0.32	0.40	0.35	0.31	0.39	0.29	0.34	0.29	0.31	0.27
9	0.36	0.28	0.34	0.37	0.26	0.44	0.33	0.27	0.37	0.36	0.32	0.33	0.36	0.26	0.36
10	0.38	0.41	0.35	0.38	0.26	0.33	0.29	0.34	0.33	0.30	0.30	0.35	0.34	0.29	0.31

Table 1.10 Effects of harvest date on chilling injury of 'Buoi' mangoes during storage at 12°C and ripening at 25°C for 4 days.

No	Harvest I			Harvest II			Harvest III		
	15d	20d	25d	15d	20d	25d	15d	20d	25d
1	0	1	3	0	1	2	0	0	3
2	0	0	3	0	0	2	0	0	1
3	0	1	3	0	1	3	0	1	2
4	0	1	2	0	0	2	0	1	2
5	0	0	2	0	0	1	0	0	1
6	0	1	3	0	0	2	0	0	2
7	0	1	3	0	1	1	0	1	2
8	0	2	1	0	1	3	0	0	1
9	0	1	3	0	0	2	0	0	2
10	0	0	2	0	0	1	0	0	2

Table 1.11 Effects of harvest date on eating quality of 'Buoi' mangoes during storage at 12°C and ripening at 25°C for 4 days.

No	Harvest I					Harvest II					Harvest III				
	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d
1	8	7	8	8	7	7	8	8	8	7	6	8	8	7	8
2	7	7	8	9	6	8	7	7	8	7	8	7	9	9	7
3	7	8	7	9	7	7	8	8	7	7	7	6	8	8	7
4	6	6	9	8	7	6	7	9	8	8	6	7	9	7	7
5	7	8	8	8	7	8	6	9	8	6	7	8	8	8	6
6	6	7	9	7	6	7	7	8	9	8	7	7	9	7	8
7	6	8	7	7	7	6	6	8	7	6	8	7	8	8	7
8	6	7	8	8	8	7	8	9	8	7	8	7	7	8	7
9	8	6	8	9	7	7	6	7	8	8	6	6	8	9	6
10	6	7	8	7	6	6	8	8	7	6	6	8	8	8	8

APPENDIX 2

Table 2.1 Effects of storage duration on postharvest quality attributes of 'Buoi' mangoes after removal from cold storage at 12°C (RH 85-90%).

Storage duration, days	Harvest I	Harvest II	Harvest III
Weight loss rate:			
5	1.71e*	1.42e	1.39e
10	2.88d	2.44d	2.36a
15	5.06c	4.37c	4.42c
20	7.82b	7.25b	7.02b
25	9.45a	8.89a	8.72a
Peel colour:			
0	1.9e	1.8e	1.9e
5	2.1de	2.2de	2.2de
10	2.4dc	2.5cd	2.7cd
15	2.7c	2.9bc	3.0bc
20	3.2b	3.3ab	3.3ab
25	3.7a	3.6a	3.7a
Pulp colour:			
0	2.0e	1.9c	1.9e
5	2.3de	2.2c	2.2de
10	2.6cd	2.7b	2.6cd
15	2.9bc	3.0b	3.1bc
20	3.3ab	3.4a	3.4ab
25	3.6a	3.7a	3.7a
Firmness:			
0	66.1a	63.4a	63.1a
5	59.0b	56.2b	56.1b
10	53.1c	51.8c	50.5c
15	44.8d	44.1d	44.5d
20	41.8c	40.7e	40.3e
25	38.7f	37.6f	37.0f
Crushing stress:			
0	2789a	2546a	2449a
5	2443b	2089b	1999b
10	1678c	1568c	1500c
15	659d	721d	656d
20	338e	368e	356e
25	328e	308e	305e

(Continue Table 2.1 - Appendix 2)

SSC:			
0	6.73f	7.07f	7.19f
5	7.72e	8.21e	8.22e
10	9.06d	9.57d	9.67d
15	10.41c	10.61c	10.71c
20	12.20a	12.32a	12.31a
25	12.13b	11.58b	11.51b
Total acidity:			
0	1.31a	1.29a	1.29a
5	1.02b	0.98b	1.00b
10	0.91c	0.86c	0.87c
15	0.82d	0.73d	0.75d
20	0.66e	0.62e	0.62e
25	0.56f	0.57f	0.53f
Chilling injury:			
15	0b	0b	-
20	0.3b	0.1b	-
25	1.9a	1.1a	-
Eating quality:			
0	2.07f	1.8f	1.9f
5	2.8e	2.8e	2.7e
10	3.7d	3.7d	3.8d
15	5.5c	5.4c	5.5c
20	7.4a	7.4a	7.4a
25	6.6b	6.5b	6.5b

*Mean in a column with the same letter are not significantly different ($P < 0.05$)

Table 2.2 Effects of storage time on postharvest quality attributes of 'Buoi' mangoes after removal from cold storage at 12°C and ripening for 4 days at 25°C.

Storage duration, days	Harvest I	Harvest II	Harvest III
SSC:			
5	13.19c*	13.32b	13.32b
10	13.36bc	13.60ab	13.52ab
15	13.71ab	13.76ab	13.72a
20	13.81a	13.83a	13.85a
25	13.61ab	13.54ab	13.68ab
Total acidity:			
5	0.371a	0.356a	0.349a
10	0.365a	0.352a	0.347a
15	0.330a	0.331a	0.321a
20	0.321a	0.321a	0.313a
25	0.321a	0.320a	0.306a
Chilling injury:			
15	0c	0b	0b
20	0.8b	0.4b	0.27b
25	2.5a	1.9a	1.63a
Eating quality:			
5	6.7b	6.9b	6.9b
10	7.1b	7.1b	7.1b
15	8.0a	8.1a	8.2a
20	8.0a	7.8a	7.9a
25	6.8b	7.0a	7.1b

*Mean in a column with the same letter are not significantly different ($P < 0.05$)

Table 2.3 Effects of harvest date on postharvest quality attributes of 'Buoi' mangoes after removal from cold storage at 12°C (RH 85-90%).

Harvest	Storage duration, days					
	0	5	10	15	20	25
Weight loss:						
I	-	1.71a*	2.88a	5.06a	7.82a	9.45a
II	-	1.42b	2.44b	4.37b	7.25b	8.89b
III	-	1.39b	2.36b	4.42b	7.02b	8.72b
Peel colour:						
I	1.9a	2.1a	2.4a	2.7a	3.2a	3.7a
II	1.8a	2.2a	2.5a	2.9a	3.3a	3.6a
III	1.9a	2.2a	2.7a	3.0a	3.3a	3.7a
Pulp colour:						
I	2.0a	2.3a	2.6a	2.9a	3.3a	3.6a
II	1.9a	2.2a	2.7a	3.0a	3.4a	3.7a
III	1.9a	2.2a	2.6a	3.1a	3.4a	3.7a
Firmness:						
I	66.1a	59.0a	53.1a	44.8a	41.8a	38.7a
II	63.4b	56.2b	51.8ab	44.1a	40.7a	37.6a
III	63.1b	56.1b	50.5b	44.5a	40.3a	37.0a
Crush stress:						
I	2789a	2443a	1678a	659a	338a	328a
II	2546b	2089b	1568ab	721a	368a	308a
III	2449b	1999b	1500b	656a	356a	305a
SSC:						
I	6.73b	7.72b	9.06b	10.41a	12.20a	12.13a
II	7.07a	8.21b	9.57a	10.61a	12.32a	11.58a
III	7.19a	8.22a	9.67a	10.71a	12.31a	11.51a
Acidity:						
I	1.310a	1.015a	0.907a	0.815a	0.659a	0.562a
II	1.287a	0.978a	0.857ab	0.733b	0.621a	0.574a
III	1.293a	0.997a	0.874b	0.746b	0.618a	0.532a
Chilling injury:						
I	-	0	0	0	0.3a	1.9a
II	-	0	0	0	0.1a	1.1b
III	-	0	0	0	0a	1.0b

(Continue Table 2.3 - Appendix 2)

Eating Quality:						
I	2.0a	2.8a	3.7a	5.5a	7.4a	6.6a
II	1.8a	2.8a	3.7a	5.4a	7.4a	6.5a
III	1.9a	2.7a	3.8a	5.5a	7.4a	6.5a

*Mean in a column with the same letter are not significantly different (P < 0.05)

Table 2.4 Effects of harvest date on postharvest quality attributes of 'Buoi' mangoes after removal from cold storage and ripening at 25°C for 4 days.

Harvest	Storage duration, days				
	5	10	15	20	25
SSC:					
I	13.19a*	13.36a	13.71a	13.81a	13.61a
II	13.32a	13.60a	13.76a	13.83a	13.54a
III	13.32a	13.52a	13.72a	13.85a	13.68a
Acidity:					
I	0.371a	0.365a	0.330a	0.321a	0.321a
II	0.356a	0.352a	0.331a	0.321a	0.320a
III	0.349a	0.347a	0.321a	0.313a	0.306a
Chilling injury:					
I	0	0	0	0.8a	2.5a
II	0	0	0	0.4b	1.9b
III	0	0	0	0.3b	1.8b
Eating quality:					
I	6.7a	7.1a	8.0a	8.0a	6.8a
II	6.9a	7.1a	8.1a	8.1a	7.0a
III	6.9a	7.1a	8.2a	8.2a	7.1a

*Mean in a column with the same letter are not significantly different (P < 0.05)

APPENDIX 3

Table 3.1 Effects of storage temp. on weight loss rate (%) 'Buoi' mangoes during storage at different temperatures.

No	7°C					12°C					7°C					Ambient Temp.		
	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d
1	1.10	1.97	3.23	4.09	5.51	1.26	2.21	4.31	7.33	8.56	2.66	4.74	5.90	10.21	11.50	4.88	10.67	15.74
2	1.15	2.17	2.92	4.71	5.86	1.50	2.49	4.00	6.94	8.87	2.19	4.11	6.32	9.24	11.50	4.33	10.70	14.91
3	1.20	1.95	3.30	4.11	5.68	1.43	2.81	3.98	7.53	8.72	2.19	4.22	6.98	8.80	11.93	4.78	10.54	16.73
4	0.97	2.17	3.57	5.11	5.30	1.45	2.72	4.14	7.32	9.43	2.12	3.74	7.36	8.89	11.83	4.08	9.20	16.84
5	0.92	2.19	2.43	4.98	5.94	1.27	2.36	4.26	7.87	9.15	2.62	4.61	6.50	8.92	12.01	4.49	10.16	15.34
6	1.08	1.92	2.92	4.63	5.75	1.44	2.52	4.46	6.96	8.69	2.37	4.15	6.49	8.94	11.60	4.16	9.09	15.36
7	0.94	2.01	2.69	4.46	5.76	1.55	2.70	5.02	7.11	9.30	2.83	4.18	6.27	10.36	11.61	4.02	10.84	16.77
8	1.02	1.97	3.39	4.08	4.84	1.51	2.55	4.36	6.97	8.96	2.73	4.31	6.72	10.32	11.33	3.97	10.79	16.55
9	1.15	1.84	3.44	3.87	5.69	1.52	2.50	4.43	6.73	8.65	2.31	4.04	7.57	8.58	11.76	3.80	11.05	16.83
10	1.23	2.32	2.97	4.77	6.15	1.39	2.07	4.22	6.72	9.05	2.69	4.38	6.42	9.65	11.72	3.31	10.78	14.86
11	1.23	1.67	3.63	5.13	4.76	1.37	2.30	4.43	6.99	9.21	3.10	3.90	7.53	8.02	11.88	2.96	9.70	15.75
12	1.08	1.97	2.51	5.12	4.66	1.45	2.56	4.37	7.85	9.10	2.04	4.06	7.57	9.84	11.59	3.89	9.27	16.00
13	1.06	1.89	2.68	4.11	5.63	1.58	2.56	4.29	7.63	8.78	2.81	4.09	7.28	9.54	11.41	3.27	9.17	15.67
14	1.24	2.05	3.53	4.81	5.28	1.37	2.54	4.24	7.03	8.89	2.26	4.11	8.30	8.66	11.85	2.97	9.07	16.61
15	1.23	2.33	3.93	4.86	6.30	1.46	2.22	4.24	7.43	8.96	2.14	4.93	6.23	10.25	11.39	3.71	8.93	15.88
16	1.19	1.83	3.48	4.35	5.38	1.27	2.47	4.59	7.74	8.74	2.52	4.48	7.00	9.83	11.87	4.27	8.91	16.71
17	1.12	2.00	3.47	4.69	5.92	1.25	2.23	4.26	6.85	8.74	2.18	3.64	7.75	8.36	11.70	3.19	9.41	16.69
18	1.32	1.93	3.65	4.04	5.26	1.60	2.49	5.10	7.30	8.51	2.15	3.75	7.43	9.81	10.87	2.81	9.19	15.70.
19	1.20	1.70	2.95	4.84	5.67	1.58	2.38	4.24	7.67	8.52	1.97	5.01	6.45	9.69	12.00	3.91	10.06	15.90
20	1.17	1.82	3.30	4.52	5.42	1.26	2.30	4.47	7.41	9.09	2.54	4.03	6.36	8.99	11.59	4.47	8.92	15.62

Table 3.2 Effects of storage temp. on colour 'Buoi' mangoes during storage at different temperatures.

PEEL COLOUR index

No	7°C						12°C					17°C					Ambient Temp.		
	0d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d
1	2	2	2	3	3	3	2	3	3	4	4	3	3	4	4	5	3	4	5
2	2	2	3	3	3	3	2	2	3	4	4	2	3	3	4	4	3	4	5
3	2	2	2	2	2	3	2	2	3	3	4	2	3	4	4	4	3	5	5
4	2	2	2	2	3	3	2	3	3	3	4	2	2	3	4	4	3	4	5
5	2	2	2	2	3	2	2	2	3	3	3	3	3	3	5	5	4	4	5
6	1	2	2	2	2	3	2	3	3	3	4	2	3	4	4	5	3	5	5
7	2	2	2	3	3	3	2	2	3	3	4	2	3	4	4	5	3	4	5
8	1	2	2	3	3	3	3	2	3	3	3	3	3	3	5	5	4	4	5
9	2	2	2	2	3	4	2	3	2	3	3	2	3	4	3	5	3	4	5
10	2	2	3	3	3	3	3	3	3	4	3	3	3	3	3	4	3	4	5

PULP COLOUR index

No	7°C						12°C					17°C					Ambient Temp.		
	0d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d
1	2	2	2	3	3	3	2	3	3	4	4	3	3	3	4	5	3	4	5
2	2	2	3	3	3	3	3	2	3	3	4	2	3	4	3	4	3	4	5
3	2	2	2	2	2	3	2	3	3	4	4	2	3	4	4	4	2	5	5
4	2	2	2	2	3	4	2	3	3	3	4	2	3	3	5	5	4	4	5
5	2	2	3	2	3	2	2	3	3	3	3	3	3	3	4	5	4	4	4
6	2	3	2	2	2	3	2	2	3	4	4	2	3	5	4	5	3	5	5
7	1	2	2	3	3	4	2	3	3	3	4	2	3	3	5	4	3	4	5
8	2	2	3	3	3	3	2	2	3	3	4	2	2	3	4	5	3	4	5
9	2	2	2	3	3	3	2	3	3	3	3	3	4	4	4	5	3	4	5
10	2	2	2	3	4	3	3	3	3	4	3	3	3	4	4	5	3	4	5

Table 3.3 Effects of storage temp. on texture 'Buoi' mangoes during storage at different temperatures.

FIRMNESS, N

No	7°C						12°C					17°C					Ambient Temp.		
	0d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d
1	64	61	59	52	48	39	60	53	45	42	38	54	47	39	32	31	45	33	29
2	62	61	52	49	43	40	53	54	46	40	36	56	41	36	31	32	44	33	26
3	65	62	62	47	48	38	54	51	42	38	42	54	45	39	30	31	43	33	27
4	67	63	58	46	42	40	61	51	48	44	38	53	42	37	36	29	44	36	29
5	64	59	53	53	41	49	57	54	46	36	39	52	46	40	32	29	40	34	26
6	68	62	56	50	50	48	57	49	42	43	40	53	43	37	30	30	39	31	25
7	60	57	59	53	49	39	56	50	42	41	35	54	40	34	33	30	40	30	26
8	61	65	61	48	46	43	53	57	45	39	36	53	42	36	34	32	45	32	25
9	60	52	52	52	45	46	56	51	43	44	35	55	45	33	33	32	40	30	27
10	63	59	56	50	47	42	55	48	42	40	37	54	46	35	35	31	43	29	27

CRUSHING STRESS, kPa

No	7°C						12°C					17°C					Ambient Temp.		
	0d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15dd	20d	25d	5d	10d	15d
1	2590	2355	1941	1160	801	640	2242	1456	749	343	343	1749	988	471	252	232	1039	340	231
2	2556	2170	1971	1233	908	606	1836	1805	799	298	330	2050	918	425	248	248	1007	331	187
3	2222	2387	1677	1388	888	600	1945	1353	680	334	264	1804	1059	426	203	227	1034	358	188
4	2574	2085	1767	1331	739	554	2373	1799	680	403	264	1894	990	383	226	200	1141	335	220
5	2681	2194	1942	1301	890	634	2151	1353	790	318	304	1516	1017	506	282	235	997	299	166
6	2508	2216	1731	1288	852	598	2166	1688	690	384	327	1665	1056	449	262	189	1097	259	251
7	2416	1941	1756	1299	900	600	2170	1561	716	310	332	1830	930	402	211	256	984	333	171
8	2645	2556	1655	1280	764	690	1920	1528	714	438	314	1654	958	405	272	185	1078	274	158
9	2697	1867	1616	1236	852	614	2099	1578	680	478	287	1990	985	435	255	254	1026	250	180
10	2576	2122	1599	1289	803	601	1989	1558	708	383	317	1840	938	426	246	236	1020	314	196

Table 3.4 Effects of storage temp. on SSC (%) 'Buoi' mangoes during storage at different temperatures.

No	7°C						12°C					17°C					Ambient Temp.		
	0d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d
1	7.4	7.5	8.9	9.2	11.3	10.4	7.6	10.4	11.0	11.6	13.3	8.6	10.8	11.0	12.5	12.0	12.5	13.2	11.5
2	7.2	7.4	8.6	9.3	10.2	9.9	7.7	9.8	10.9	12.4	12.1	9.0	11.1	11.7	13.0	12.3	12.5	13.3	11.6
3	7.0	7.4	8.3	8.6	10.6	9.2	8.6	9.1	10.4	13.0	10.2	8.8	10.0	12.0	13.4	11.8	12.7	12.7	11.2
4	7.2	7.6	8.0	8.9	11.5	10.4	9.0	9.2	10.3	12.8	11.2	9.4	10.0	11.2	13.3	12.8	14.0	13.4	11.3
5	7.3	7.8	8.0	8.4	10.3	10.8	8.0	9.7	11.0	12.9	11.6	8.8	11.0	11.4	12.8	11.9	15.0	13.3	13.7
6	6.7	7.5	7.9	9.6	10.9	9.3	8.0	9.5	10.1	13.2	11.1	8.5	9.8	12.4	12.6	11.5	12.9	15.3	11.7
7	6.9	8.3	8.5	8.9	10.8	9.6	7.7	10.2	11.2	12.8	10.8	9.2	10.6	10.9	12.9	12.8	12.5	13.7	12.6
8	7.0	7.6	7.9	9.6	10.7	9.6	8.6	9.6	10.1	11.2	11.2	8.7	10.6	10.9	12.6	12.7	14.0	14.6	13.2
9	6.9	8.5	8.3	8.7	11.5	10.0	8.4	9.5	10.3	11.9	11.6	8.5	10.2	12.3	12.8	12.5	13.0	13.2	12.1
10	7.1	7.2	8.8	9.7	11.5	10.6	8.5	8.7	10.8	11.4	12.7	8.6	11.4	11.6	13.2	12.3	11.3	12.9	13.6

Table 3.5 Effects of storage temp. on total acidity (%) 'Buoi' mangoes during storage at different temperatures.

No	7°C						12°C					17°C					Ambient Temp.		
	0d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d
1	1.28	1.05	0.95	0.92	0.79	0.90	0.90	0.91	0.72	0.66	0.63	0.87	0.72	0.67	0.53	0.46	0.67	0.38	0.21
2	1.36	1.15	0.91	0.89	0.75	0.74	1.05	0.92	0.70	0.59	0.55	0.96	0.75	0.61	0.49	0.49	0.62	0.41	0.19
3	1.23	1.06	1.08	0.85	0.86	0.65	1.03	0.80	0.69	0.67	0.57	0.98	0.73	0.62	0.52	0.49	0.68	0.37	0.26
4	1.29	1.10	0.93	0.96	0.82	0.58	0.92	0.92	0.79	0.66	0.54	0.91	0.71	0.58	0.49	0.45	0.60	0.42	0.31
5	1.34	1.10	1.01	0.93	0.76	0.95	1.03	0.89	0.68	0.59	0.60	0.92	0.76	0.71	0.58	0.50	0.72	0.35	0.23
6	1.24	1.12	0.99	0.89	0.83	0.97	0.93	0.76	0.73	0.65	0.52	0.85	0.72	0.55	0.54	0.45	0.63	0.36	0.29
7	1.22	1.08	1.10	0.95	0.85	0.61	1.00	0.89	0.71	0.61	0.62	1.02	0.82	0.71	0.53	0.49	0.68	0.33	0.32
8	1.33	1.08	0.92	0.86	0.85	0.67	0.97	0.79	0.81	0.59	0.56	0.86	0.75	0.64	0.47	0.48	0.66	0.41	0.43
9	1.27	1.20	0.96	0.89	0.81	0.59	0.94	0.78	0.78	0.62	0.54	0.89	0.81	0.56	0.55	0.50	0.62	0.35	0.27
10	1.31	1.09	1.06	0.85	0.76	0.82	1.01	0.91	0.72	0.57	0.61	0.91	0.72	0.54	0.57	0.46	0.63	0.39	0.32

Table 3.6 Effects of storage temp. on chilling injury 'Buoi' mangoes during storage at different temperatures.

No	7°C			12°C		
	15d	20d	25d	15d	20d	25d
1	1	2	3	0	0	0
2	0	2	3	0	0	2
3	0	1	2	0	0	1
4	0	2	3	0	0	1
5	0	2	2	0	0	1
6	1	1	3	0	0	1
7	0	1	2	0	0	0
8	0	3	3	0	1	1
9	1	1	2	0	0	2
10	0	2	3	0	0	2

Table 3.7 Effects of storage temp. on eating quality 'Buoi' mangoes during storage at different temperatures.

No	7°C						12°C					17°C					Ambient Temp.		
	0d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d
1	1	3	4	5	7	6	3	4	6	8	7	3	5	6	8	7	5	7	5
2	2	2	3	4	6	6	3	3	5	7	8	4	4	6	8	7	6	6	6
3	2	2	4	5	7	6	3	5	5	8	6	3	4	7	6	6	7	7	6
4	2	2	4	5	6	5	2	4	5	8	6	4	4	6	7	5	6	6	5
5	2	3	3	4	7	6	3	3	6	7	6	3	5	6	8	6	5	6	6
6	2	3	3	6	6	7	3	4	5	7	7	3	4	7	8	7	6	8	7
7	2	2	3	5	6	6	3	3	6	6	6	3	5	6	7	6	6	8	5
8	2	3	4	4	5	5	2	4	6	8	6	4	5	7	6	7	6	6	6
9	2	2	3	5	7	5	3	4	5	7	6	3	4	5	7	5	5	6	6
10	1	3	4	5	6	6	3	3	5	7	7	4	5	6	8	7	6	8	6

Table 3.8 Effects of storage temp. on SSC 'Buoi' mangoes during storage at different temperatures.

No	7°C					12°C					17°C					Ambient Temp.		
	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d
1	11.1	12.3	12.4	12.1	12.3	13.5	13.5	14.2	13.4	14.3	12.9	13.2	14.2	13.2	12.1	12.9	13.2	13.6
2	11.5	11.8	13.2	12.2	12.1	12.7	14.2	13.5	13.5	13.9	13.2	13.7	14.4	14.3	14.2	13.1	12.9	12.6
3	11.8	12.7	11.9	12.1	11.9	13.2	12.9	13.7	13.9	14.6	12.9	13.8	13.9	13.7	14.1	12.9	13.1	13.5
4	12.3	13.2	12.6	12.7	12.5	13.6	13.6	14.4	14.2	13.6	12.6	13.5	14.6	14.1	12.9	13.5	14.2	12.5
5	11.7	13.0	12.7	11.9	12.1	14.4	13.6	13.8	13.8	12.5	13.9	13.2	14.1	12.4	12.1	13.0	13.7	12.2
6	13.1	11.9	13.4	13.0	12.6	13.1	13.6	13.9	14.3	13.5	12.7	13.7	14.1	14.3	14.1	13.2	13.0	11.8
7	11.8	12.3	12.3	12.1	11.5	12.9	13.3	13.1	13.1	13.7	13.6	12.8	13.7	13.9	13.6	14.2	13.6	12.6
8	12.1	12.4	12.6	12.2	13.4	13.4	14.1	14.2	14.6	12.9	13.5	12.6	13.6	13.9	12.4	12.5	12.9	11.9
9	12.4	11.7	13.2	12.4	11.8	13.6	13.3	13.8	13.7	12.7	12.5	13.5	12.5	13.7	12.2	13.1	12.5	12.5
10	11.4	12.1	11.9	13.1	12.6	12.8	13.9	13.0	13.8	13.7	12.5	13.4	13.9	13.8	13.5	12.7	13.3	12.3

Table 3.9 Effects of storage temp. on SSC 'Buoi' mangoes during storage at different temperatures.

No	7°C					12°C					17°C					Ambient Temp.		
	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d
1	0.39	0.31	0.32	0.39	0.32	0.29	0.42	0.29	0.33	0.25	0.23	0.23	0.21	0.33	0.37	0.23	0.32	0.24
2	0.38	0.29	0.35	0.32	0.35	0.44	0.39	0.33	0.31	0.34	0.32	0.31	0.28	0.39	0.20	0.35	0.40	0.25
3	0.30	0.36	0.33	0.39	0.31	0.35	0.41	0.31	0.36	0.31	0.20	0.23	0.25	0.30	0.24	0.24	0.27	0.25
4	0.29	0.31	0.34	0.30	0.29	0.41	0.28	0.33	0.28	0.37	0.22	0.24	0.37	0.20	0.29	0.29	0.21	0.35
5	0.39	0.32	0.29	0.39	0.26	0.34	0.39	0.34	0.23	0.59	0.29	0.35	0.37	0.30	0.29	0.25	0.25	0.24
6	0.27	0.35	0.36	0.30	0.35	0.27	0.29	0.26	0.33	0.29	0.24	0.30	0.29	0.17	0.20	0.31	0.29	0.25
7	0.32	0.41	0.32	0.42	0.54	0.43	0.32	0.39	0.35	0.31	0.33	0.20	0.27	0.24	0.28	0.26	0.36	0.31
8	0.31	0.29	0.36	0.29	0.29	0.32	0.40	0.35	0.31	0.39	0.31	0.22	0.30	0.39	0.33	0.26	0.31	0.23
9	0.26	0.33	0.39	0.35	0.41	0.44	0.33	0.27	0.37	0.36	0.23	0.31	0.37	0.24	0.37	0.32	0.25	0.27
10	0.34	0.39	0.41	0.37	0.32	0.33	0.29	0.34	0.33	0.30	0.25	0.33	0.34	0.30	0.24	0.20	0.32	0.26

Table 3.10 Effects of storage temp. on SSC 'Buoi' mango during storage at different temperatures.

No	7°C			12°C		
	15d	20d	25d	15d	20d	25d
1	1	3	4	0	1	2
2	0	3	4	0	0	2
3	1	3	4	0	1	3
4	2	2	4	0	0	2
5	0	3	3	0	0	1
6	0	3	3	0	0	2
7	1	4	3	0	1	1
8	2	2	4	0	1	3
9	0	2	3	0	0	2
10	1	4	3	0	0	1

Table 3.11 Effects of storage temp. on eating quality 'Buoi' mangoes during storage at different temperatures.

No	7°C					12°C					17°C					Ambient Temp.		
	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d	20d	25d	5d	10d	15d
1	6	6	7	6	4	7	8	8	8	7	8	8	8	7	3	6	6	3
2	5	7	7	5	6	8	7	7	8	7	8	8	9	8	4	7	5	2
3	6	6	6	7	6	7	8	8	7	7	7	9	9	6	3	8	7	3
4	6	8	8	6	4	6	7	9	8	8	9	9	8	8	4	6	6	2
5	6	6	7	5	5	8	6	9	8	6	8	8	9	7	3	7	6	3
6	6	7	7	5	4	7	7	8	9	8	8	8	9	8	4	6	7	4
7	6	7	6	6	6	6	6	8	7	6	9	9	9	6	4	6	6	3
8	5	6	6	6	5	7	8	9	8	7	9	8	8	8	3	7	5	2
9	7	6	7	7	4	7	6	7	8	8	7	8	9	8	4	7	6	2
10	5	6	6	6	5	6	8	8	7	6	8	9	8	7	4	6	7	3

APPENDIX 4

Table 4.1 Effects of storage duration on postharvest quality attributes of 'Buoi' mangoes after removal from cold storage at different temp.

Storage duration, days	7°C	12°C	17°C	Ambient temp.
Weight loss rate:				
5	1.13e*	1.42e	2.42e	3.86c
10	1.99d	2.44d	4.22d	9.82b
15	3.50c	4.37c	6.92c	16.02a
20	4.55b	7.25b	9.35b	-
25	5.54a	8.89a	11.65a	-
Peel colour:				
0	1.8e	1.8e	1.8f	1.8d
5	2.0de	2.2de	2.4e	3.2c
10	2.2cd	2.5cd	2.9d	4.2b
15	2.5bc	2.9bc	3.5c	5.0a
20	2.8ab	3.3ab	4.0b	-
25	3.0a	3.6a	4.6a	-
Pulp colour:				
0	1.9d	1.9c	1.9f	1.9d
5	2.1d	2.2c	2.4c	3.1c
10	2.3cd	2.7b	3.0d	4.2b
15	2.6bc	3.0b	3.6c	4.9a
20	2.9ab	3.4a	4.1b	-
25	3.1a	3.7a	4.7a	-
Firmness:				
0	63.4a	63.4a	63.4a	63.4a
5	60.1b	56.2b	53.8b	42.3b
10	58.8c	51.8c	43.7c	32.1c
15	50.0d	44.1d	36.6d	26.7d
20	45.9e	40.7e	32.6e	-
25	42.4f	37.6f	30.7f	-
Crushing stress:				
0	2546a	2546a	2546a	2546a
5	2189b	2089b	1799b	1042b
10	1766c	1568c	984c	309c
15	1281d	721d	433d	194d
20	840e	368c	246e	-
25	613f	308c	226e	-

(Continue Table 4.1 - Appendix 4)

SSC:				
0	7.07f	7.07f	7.07f	7.07c
5	7.68e	8.21e	8.81e	12.04a
10	8.32d	9.57d	10.55d	12.56a
15	9.09c	10.61c	11.54c	11.25b
20	10.93a	12.32a	12.91a	-
25	9.98b	11.58b	12.26b	-
Total acidity:				
0	1.29a	1.29a	1.29a	1.29a
5	1.10b	0.98b	0.92b	0.65b
10	0.99c	0.86c	0.75c	0.38c
15	0.90d	0.73d	0.62d	0.28d
20	0.81e	0.62e	0.53e	-
25	0.75f	0.57f	0.48f	-
Chilling injury:				
15	0.3c	0b	0	0
20	1.7b	0.1b	0	0
25	2.6a	1.1a	0	0
Eating quality:				
0	1.8f	1.8f	1.8e	1.8c
5	2.5e	2.8e	3.4d	5.8b
10	3.5d	3.7d	4.5c	6.8a
15	4.8c	5.4c	6.2b	5.8b
20	6.3a	7.1a	7.3a	-
25	5.8b	6.5b	6.2b	-

*Mean in a column with the same letter are not significantly different ($P < 0.05$)

Table 4.2 Effects of storage duration on postharvest quality attributes of 'Buoi' mangoes after removal from cold storage at different temp. and ripening 4 days at 25°C

Storage duration, days	7°C	12°C	17°C	Ambient temp.
SSC:				
5	11.92b*	13.32b	13.03c	13.11a
10	12.34ab	13.60ab	13.34bc	13.24a
15	12.62a	13.76ab	13.90a	12.55b
20	12.38a	13.83a	13.73ab	-
25	12.28ab	13.54ab	13.12c	-
Acidity:				
5	0.352a	0.356a	0.305a	0.304a
10	0.347a	0.352a	0.286a	0.270a
15	0.344a	0.331a	0.281a	0.269a
20	0.336a	0.321a	0.272a	-
25	0.325a	0.320a	0.262a	-
Chilling injury:				
5	0b	0b	0	0
10	0b	0b	0	0
15	0.8b	0b	0	0
20	2.9a	0.4b	0	0
25	3.5a	1.9a	0	0
Eating quality:				
5	5.8c	6.9b	8.1a	6.6a
10	6.5ab	7.1b	8.4a	6.1a
15	6.7a	8.1a	8.6a	2.7b
20	5.9bc	7.8a	7.3b	-
25	4.9d	7.0b	3.6c	-

*Mean in a column with the same letter are not significantly different ($P < 0.05$)

Table 4.3 Effects of storage temperature on postharvest quality attributes of 'Buoi' mangoes during storage after removal from cold storage.

Storage temperature, °C	Storage duration, days				
	5	10	15	20	25
Weight loss:					
7	1.13d*	1.99d	3.50d	4.55c	5.54c
12	1.42c	2.44c	4.37c	7.25b	8.89b
17	2.42b	4.22b	6.92b	9.35a	11.65a
27	3.86a	9.82a	16.02a	-	-
Peel colour:					
7	2.0c	2.2c	2.5d	2.8c	3.0c
12	2.2bc	2.5bc	2.9c	3.3b	3.6b
17	2.4b	2.9b	3.5b	4.0a	4.6a
27	3.2a	4.2a	5.0a	-	-
Pulp colour:					
7	2.1b	2.3c	2.6c	2.9b	3.1c
12	2.2b	2.7bc	3.0c	3.4b	3.7b
17	2.4b	3.0b	3.6b	4.1a	4.7a
27	3.1a	4.2a	4.9a	-	-
Firmness:					
7	60.1a	58.8a	50.0a	45.9a	42.4a
12	56.2b	51.8b	44.1b	40.7b	37.6b
17	53.8c	43.7c	36.6c	32.6c	30.7c
27	42.3d	32.1d	26.7d	-	-
Crushing stress:					
7	2189a	1766a	1281a	840a	613a
12	2089a	1568b	721b	368b	308b
17	1799b	984c	433c	246c	226c
27	1042c	304d	194d	-	-
SSC:					
7	7.68d	8.32d	9.09c	10.93b	9.98c
12	8.21c	9.57c	10.61b	12.32ab	11.58b
17	8.81b	10.55b	11.54a	12.91a	12.27a
27	12.04a	12.56a	11.25a	-	-

(Continue Table 4.3 - Appendix 4)

Acidity:					
7	1.10a	0.99a	0.90a	0.81a	0.75a
12	0.98ab	0.86b	0.73b	0.62b	0.57b
17	0.92b	0.75c	0.62c	0.53c	0.48c
27	0.65c	0.38d	0.28d	-	-
Chilling injury:					
7	0	0	0.3a	1.7a	2.6a
12	0	0	0a	0.1b	1.1b
17	-	-	-	-	-
27	-	-	-	-	-
Eating quality:					
7	2.5c	3.5c	4.8c	6.3b	5.8c
12	2.8c	3.7c	5.4b	7.1a	6.5a
17	3.4b	4.5b	6.2a	7.3a	6.2b
27	5.8a	6.8a	5.8ab	-	-

*Mean in a column with the same letter are not significantly different ($P < 0.05$)

Table 4.4 Effects of storage temperature on postharvest quality attributes of 'Buoi' mangoes after removal from cold storage and ripening for 4 days at 25°C.

Storage temp., oC	Storage duration, days				
	5	10	15	20	25
SSC:					
7	11.92b*	12.34b	12.62b	12.38b	12.28b
12	13.32a	13.60a	13.76a	13.83a	13.54a
17	13.03a	13.34a	13.90a	13.73a	13.12a
27	13.11a	13.24a	12.55b	-	-
Acidity:					
7	0.352a	0.347a	0.344a	0.336a	0.325a
12	0.356a	0.352a	0.331a	0.321a	0.320a
17	0.305b	0.286b	0.281b	0.272b	0.262b
27	0.304b	0.270b	0.269b	-	-
Chilling injury:					
7	0	0	0.8a	2.9a	3.5a
12	0	0	0b	0.4b	1.9b
17	-	-	-	-	-
27	-	-	-	-	-
Eating quality:					
7	5.8c	6.5c	6.7b	5.9b	4.9b
12	6.9b	7.1b	8.1a	7.8a	7.0a
17	8.1a	8.4a	8.6a	7.3a	3.6c
27	6.6b	6.1c	2.7c	-	-

*Mean in a column with the same letter are not significantly different ($P < 0.05$)