EFFECT OF MIXED LOADING OF BANANA (*Musa paradisiaca* cv. Berangan) WITH PINEAPPLE (*Ananas comosus* cv. Josapine) AT OPTIMUM STORAGE TEMPERATURE

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By
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ENDORSEMENT

The project report entitled **Effect of Mixed Loading of Banana (*Musa paradisiaca* cv. Berangan) with Pineapple (*Ananas comosus* cv. Josapine) at Optimum Storage Temperature** by **Chiew Lay Im**, Matric No. **UK 15072** has been reviewed and corrections have been made according to the recommendations by examiners. This report is submitted to the Department of Agrotechnology in partial fulfillment of the requirement of the degree of Bachelor of Science in Agrotechnology (Post Harvest Technology), Faculty of Agrotechnology and Food Science, Universiti Malaysia Terengganu.

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DECLARATION

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ABSTRACT

Bananas intended for export are harvested at unripe stage as bananas ripened on plant often split, have poor texture and tend to be mealy. Thus, they are needed to be artificially ripened in ripening room once they arrive at destination before they can be at the point of sale. However, precise and well-controlled condition of ripening room is required and this in turn increases the total cost of the post-harvest handling of banana. This subsequently gives rise to its price. Therefore, mixed loading of banana with other fruits, such as pineapple, can be an alternative way to trigger the ripening of banana. This project was carried out to study the effects of mixed loading of bananas with pineapples at optimum storage temperature (13±1°C) for 12 days. In this project, 1 kg of bananas were packed together with pineapples in 1:0 (control), 1:1, 1:2 and 1:3 ratio by weight (kg). Ripening of bananas was examined every 3 days based on the changes on skin colour, pulp firmness, starch content, TSS content and weight loss. The statistical analysis indicates that bananas from treatment of 1:3 changed significantly on day 3 for all the parameters except weight loss, implying that the ripening was induced before day 3 while those from treatment of 1:2 changed significantly on day 6, indicating that ripening was initiated after day 3. Bananas from treatment of 1:1 showed significant changes into yellow colour after day 6. Throughout the storage period, bananas from treatment of 1:1 and control exhibited significant different from treatment of 1:2 and 1:3, implying that their ripening commencement was triggered much slower. Thus, it could be suggested that weight ratio of 1:3 could be used to induce ripening of bananas more rapidly compared to the other treatments and control.

ABSTRAK

Pisang yang ditanam untuk tujuan ekspot perlu dituai pada tahap sebelum masak kerana pisang yang dibiarkan masak di atas pokok biasanya akan menunjukkan kualiti yang kurang memuaskan. Oleh itu, pisang tersebut akan dirangsang untuk masak di dalam bilik pemasakan sesampainya di destinasi sebelum boleh dijual di pasaran. Kawalan yang tepat dan baik amat diperlukan bagi memastikan kemasakan buah yang diingini dapat dicapai. Ini meyebabkan penambahan kos pengendalian lepas tuai pisang tersebut dan seterusnya meningkatkan harga pisang. Oleh itu, simpanan campuran antara pisang dengan nanas boleh dijadikan sebagai satu cara alternatif untuk merangsang kemasakan buah pisang. Projek ini telah dijalankan untuk mengkaji kesan simpanan campuran antara dua jenis buah tersebut di bawah suhu optimum (13±1˚C) selama 12 hari. Dalam projek ini, 1 kg pisang disimpan bersama dengan nanas mengikut nisbah berat yang berlainan seperti berikut: 1:0 (kawalan), 1:1, 1:2 and 1:3. Kemasakan buah pisang diuji setiap 3 hari berdasarkan perubahan dalam warna kulit, ketegaran isi, berat buah, kandungan kanji dan jumlah pepejal terlarut. Keputusan menunjukkan pisang yang disimpan mengikut nisbah 1:3 dan 1:2 masing-masing mempunyai perubahan yang sangat ketara dalam semua parameter yang diuji kecuali perubahan berat buah pada hari ke-3 dan hari ke-6. Ini menunjukkan kemasakan buah telah dirangsang sebelum hari ke-3 bagi pisang dari nisbah 1:3 dan selepas hari ke-3 untuk pisang dari nisbah 1:2. Pisang dari nisbah 1:1 menunjukkan perubahan warna yang ketara selepas hari ke-6. Sepanjang tempoh simpanan campuran dijalankan, pisang dari nisbah 1:1 dan kawalan mempunyai perbezaan ketara dengan pisang dari nisbah 1:2 dan 1:3. Ini menunjukkan kemasakan buah berlaku lebih lambat untuk pisang dari nisbah 1:1 dan kawalan. Justeru, nisbah berat 1:3 boleh digunakan untuk merangsang kemasakan buah pisang dengan lebih cepat berbanding dengan nisbah yang lain dan kawalan.

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LIST OF ABBREVIATIONS

L	Length
W	Width
H	Height
RH	Relative Humidity
L*	Lightness
a*	Greenness (-) to redness (+)
b*	Blueness (-) to yellowness (+)
cm	Centimeter
g	Gram
kg	Kilogram
s	Second
mm	Milimiter
µL/L	Microliter per liter
° Brix	Degree of Brix
°C	Degree Celsius
%	Percentage
±	Plus minus
<	Less than
>	More than

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Bananas (*Musa paradisiaca*) are grown in 122 countries, with a cultivated area of 3.8 million hectares and a total production of 56.4 million metric tonnes. In Malaysia, banana is the second most widely cultivated fruit, covering about 26,000 ha with a total production of 530,000 metric tonnes. About 50% of the banana growing land is cultivated with Pisang Berangan and the Cavendish type, and the remaining popular cultivars are Pisang Mas, Pisang Rastali, Pisang Raja, Pisang Awak, Pisang Abu, Pisang Nangka and Pisang Tanduk. Bananas are cultivated for local consumption by smallholders, and only about 12% of the total production is exported, mainly to Singapore, Brunei, Hong Kong and the Middle East (Mak. *et al.*, 2008).

1.2 Problem statement

The banana fruits intended for export are harvested in the unripe stage where the fruits are still green and firm because banana ripened on the plant often split, have poor texture, and tend to be mealy (Elhadi *et al.*, 2008). Thus, they are needed to be

artificially ripened when they arrive at their destinations before they can be at the point of sale.

In order to induce uniform ripening most commercial cultivars of bananas require exposure of 1000 μL/L ethylene for 24 hours at 14-19°C and 85-90% RH (Thompson *et al.*, 1982). In addition, the CO_2 concentration in the ripening room must be kept below 1% to prevent its effect on delaying ethylene action on ripening of bananas. Thus, precise and well-controlled condition of ripening room is inevitable in order to prevent uneven ripening and to obtain desired ripeness of fruits that is suitable for sale. This in turn increases the total cost for post harvest handling of banana and subsequently gives rise to its price.

Therefore, mixed loading of banana with other fruits such as pineapple, which is also an ethylene producer and has low sensitivity to ethylene, can be an alternative way to trigger the ripening of banana. This method can be either carried out by storage the fruits together only when they arrive at destination or be carried out along the transportation of them so that the banana will be at its desired maturity stage, which is usually stage 4 or 5 once they reach the distribution centers, retailers or wholesalers.

1.3 Significance of study

There are studies showing that mixed loading of different crops is not preferable and should be avoided if possible because of the problems of tainting from odours, effects of ethylene on quality, and incompatible common temperature and relative humidity requirements (Tan, 1996). However, very little information is yet

available on the application of mixed loading of different crops as an alternative to replace ethylene treatment in ripening room in order to trigger the ripening of fruits.

Hence, this project was conducted to study the effectiveness of mixed loading of two different fruits (banana and pineapple) to induce ripening of fruit by using different weight ratio between these two fruits.

1.4 Objective

The objectives of this project were:

- To study the effects of mixed loading of banana with pineapple during storage at their optimum temperature around 13°C.
- To determine the ratio between banana and pineapple that is most suitable to be used in triggering the ripening process of banana.
- To determine the duration of storage required to induce the ripening of banana.

CHAPTER 2

LITERATURE REVIEW

2.1 Mixed loading

Mixed loading during transportation is applied when a single truck load of fresh produce consisting of two or more products shipped together. Although mixed loading reduces transportation costs, care must be given to prevent ethylene or odor contamination (O'Brien, 1963). Contamination can be transferred from one lot or product to another that was not previously contaminated during mixed storage and mixed load distribution, especially where pallet stacking and mixed loading of wet or iced product are involved (Food Safety Guidelines, 2006).

Tan (1996) stated that it is preferable not to store different crops together. However, this is a common practice which is unavoidable in many cases, particularly at distribution or retail levels. If mixed storage cannot be avoided, it should be used for only short periods (a few days to one week) and only fruit and vegetables that are compatible are stored together. Longer mixed storage should not be used because of the problems resulted from:

- Incompatible temperature

There are some fruit and vegetables which sensitive to low temperature, where chilling injury likely to occur when they are stored at temperature below their critical storage temperature.

- Tainting from odours

Storage of different produce in same space might result in the transfer of odours between the produce. For example, storage of apple and pear with potato caused them to have a disagreeable colour and taste. Likewise, the odour of apple, citrus, onion, garlic and some tropical fruit such as jackfruit and durian is readily absorbed by other produce.

- Sensitivity to ethylene

In addition to the fruit ripening and senescence stimulation, ethylene gas (C_2H_4) also has great effect on the quality and shelf life of vegetables, for example, yellowing of broccoli and pitting of lettuce. To ensure their maximum shelf life, ethylene-producing produce should not be stored together with ethylene-sensitive produce. For instance, the deterioration speed for carrot, broccoli, lettuce and some flowers is much more rapidly if stored with apple, avocado, banana, peach, pear, plum and other produce that give off ethylene.

If possible, mixed loading should have different regimes depending on the specific combination of fruits and vegetables in store. This is assuming that ambient ethylene concentration does not exceed 1 ppm (μL/L). The University of California (Thompson *et al.*, 1999) recommends three combinations of temperature and relative humidity (RH): 1) 0-2˚C and 90-98% RH for leafy vegetables, crucifers, temperate fruits and berries; 2) 7-10˚C and 85-95% RH for citrus, subtropical fruits and fruit vegetables; 3) 13-18˚C and 85-95% RH for tropical fruits, melons, pumpkins and root vegetables.

On the other hand, Tan (1996) recommends five different storage conditions: 1) 0˚C and 90-100% RH for apples, apricots, figs, ripe kiwifruit, peaches, pears, leafy vegetables, grapes, beets, crucifers and celery; 2) 7-10˚C and 90-100 % RH for

avocados, cantaloupes, honeydew melons, guava, cucumber, snap beans, peppers, summer squash, eggplants and citrus; 3) 13˚C and 85-90% RH for bananas, cherimoya, papayas, potatoes and pumpkins; 4) 20˚C and 85-90% RH for pineapple; and 5) ambient conditions for garlic, nuts, onions, potatoes and shallots.

2.2 Banana

It is estimated that banana is the main energy source for 100 million people (Rowe, 1981). It has been classified as climacteric fruit (Biale *et al.*, 1981) and its optimum storage temperature is 13-14˚C with approximate storage life about 2-4 weeks (Marita, 1996).

Basically, there are three physiological development stages through which harvested banana passes. The first stage is the period after harvest at which the banana fruit remains firm and green for an extended period of time. Throughout this stage, there will be no significant changes in colour, texture and chemical composition. The length of this stage is depending on temperature, humidity as well as age at harvest before the onset of ripening.

At the second stage, the banana will remain green and firm and it is also referred to as pre-climacteric life or green life (Peacock, 1966; Peacock *et al.*, 1970; Blake *et al.*, 1971). Once its green life ends and ripening has been initiated, the next developmental stage for banana occurs. It is irreversible and fruit in this condition would be overripe during marketing process.

Banana possesses unique characteristic where unripe banana shows a constant low level of ethylene production. At the onset of ripening, ethylene production rise up

resulting in a sharp peak at the onset of ripening that is followed by a high respiration rate and subsequently decrease in ethylene production. This is different from other climacteric fruits, where a gradual increase of ethylene production in parallel with a respiratory climacteric rise occurs (Burg *et al.*, 1965; Seymour *et al.*, 1993).

Currently in Britain bananas are commonly ripened at 16°C, whereas in some other European countries 18°C is preferred. The amount of gas required to initiate ripening of bananas depends on their stage of maturity at harvest, the pulp temperature of the fruit and the time of exposure to the gas. Generally, very low concentrations of ethylene are sufficient to ripen the mature banana fruit, at 14-19°C. These are in the range of 1-10 ppm (μL/L) for 24 hours. However, 1000 μL/L is commonly used to ensure uniform ripening in commercial practice. This is partly because many ripening rooms are not fully gas tight and the concentration may be rapidly reduced through leakage (Thompson *et al.*, 2003). Giant Cavendish bananas from various commercial sources in the Caribbean and Latin America were found to be successfully initiated to ripen by exposure to 10 μL/L for 24 hours at 19°C (Thompson *et al.*, 1982).

From the 1990s, there has been an increasing demand for all the fruit being offered for sale in a supermarket to be of exactly the same stage of ripeness so that it has an acceptable and predictable shelf life. This has led to the development of a system called 'pressure ripening'. The system involves the circulating air in the ripening room being channelled through boxes of fruit so that ethylene gas, which initiates ripening, is in contact equally with all the fruit in the room. At the same time, the CO_2, which can delay ethylene action on the banana ripening, must be kept lower than 1%. A temperature of 18-21°C using 10 μL/L ethylene for 24 hours in 85-90% RH was recommended by Wills *et al.* (1989).

Ahmad *et al.* (2001) showed that speed of ripening of banana is influenced by the ripening temperature and ethylene. They found that ripening speed of fruits treated with 1000 μL/L ethylene at temperature 14, 16, 18 and 20˚C are 8, 6, 5.5 and 4 days respectively while those which were not treated with ethylene used 11, 9.5, 8.5 and 5.5 days to achieve colour stage 6 at the respective temperature. Thus, it can be concluded that ethylene treated banana takes relatively less time to ripen compared to untreated banana and higher temperature results in faster ripening of fruit. In addition, Smith (1989) found that the ripening cycle for banana can be as short as 4 days (>18˚C) or may be extended to 8 to10 days (at 14˚C).

The sensitivity of bananas to ethylene is very low, within the range of 0.01-1.0 μL/L (Thompson *et al.*, 1982), and it increases with increasing temperatures (Liu, 1978). The increase in the sensitivity of banana to external ethylene causes the rise in the production of ethylene in order to trigger the ripening process. Therefore, its ethylene sensitivity increases as the ripening processes advance.

Liu (1976) discovered that the ethylene did not affect the respiration rate but accelerated softening of the partially ripe or ripe bananas at 21˚C. Ripening mature green fruits for 24 hours at 20˚C with 200 μL/L ethylene accelerated ethanol formation and increased the acetaldehyde and ethanol contents of flesh tissue. When the fruits were subsequently stored in 0 or 1% O_2 atmospheres, the respiration rate was suppressed and the skin colour remained green, but ethanol production increased compared to those stored in air. Ethanol accumulation tended to cause an off-flavour, especially at 0% O_2.

An increase in temperature raises the respiration rate besides the ethylene production (Weixin *et al.*, 1993). According to Kader (1998), fruit respiration rate is

about 20-80 mgCO_2/kg/hr at 13°C, 26-140 mgCO_2/kg/hr at 15°C, 32-200 mgCO_2/kg/hr at 18°C and 40- 280 mg CO_2/kg/hr at 20°C.

However, exposure of ripe banana to temperature higher than those in the ripening range hastens softening and decay, weakens the neck, can cause splitting of the peel, and may cause poor color development (Smith *et al.*, 1987; Semple *et al.*, 1988) while exposure to temperature less than 14°C can cause uneven ripening due to chilling injury (Stover *et al.*, 1987).

The colour of the peel is used as an indicator of ripening. A scale of 1 to 7 is convenient where 1 is dark green, 2 is light green, 3 is more green than yellow, 4 is more yellow than green, 5 is yellow with green tips, 6 is fully yellow, and 7 is flecking (Kader, 1992). Bananas are usually ripened to colour stage 4 to 5 before delivery to distribution centers, retailers or wholesalers.

2.2.1 Changes of banana during ripening

The disappearance or loss of peel green colour and the corresponding increase in yellowing of the peel during ripening are the obvious manifestations in banana. The loss of green colour is due to degradation of the chlorophyll structure. External changes in peel colour during ripening often reflect changes in pulp colour (Wainwright *et al.*, 1990). Rahman *et al.* (1995) found that the yellowness of the fruits was not affected by temperatures over the range 14-25°C, but fruits ripened at 14-18°C retained more peel green colour when fully ripe than those at the higher temperatures. They also found that fruits ripened at lower temperatures were firmer

in texture, and 20°C was found to be the best ripening temperature with regard to flavour.

Under normal storage conditions, banana undergoes significant textural transformations as they pass through the ripening process. The crisp, hard and green fruit turns into a yellow fruit with tender and soft internal pulp at the optimal ripening stage, and becomes mushy as it moves towards senescence. The loss of firmness during ripening leads to lower quality and higher incidence of mechanical damage during handling and transportation. Loss of pulp firmness during ripening varies with cultivar or hybrid. Pulp firmness is often inversely related to ripening, implying that, as ripening progressed, pulp firmness declined (Smith *et al.*, 1989).

The most striking post-harvest chemical change which occurs during the post-harvest ripening of banana is the hydrolysis of starch and the accumulation of sugar such as sucrose, glucose and fructose, which are responsible for the sweetening of the fruit as it ripens (Loesecke, 1950; Palmer, 1971). In dessert banana (e.g. Cavendish) the breakdown of starch and the synthesis of sugar are usually completed at full ripeness (peel colour stage 6-7).

Lii *et al.* (1982) reported that starch will convert to sugar during ripening and lead to the increase of banana soluble solid content. However, the magnitude of increase is dependent on cultivar/hybrid. In most of the ripe fruits, sugar forms the main component of soluble solids. Since the amount of sugar in fruit usually increases as the fruit maturity and ripeness advances, the soluble solids content of the fruit can be a useful index of stage of ripeness. Soluble solids content vary between cultivar and between stages of ripeness. For instance, in some hybrids, soluble solids contents increase to a peak and then decline. The drop in total soluble solids may be

due to the conversion of sugar in the pulp to alcohol. While in some hybrids, total soluble solids continue to increase with ripening.

Pulp pH and total titratable acidity are important post-harvest quality attributes in the assessment of fruit ripening quality. In most bananas, there is a rapid decline in pulp pH in response to increasing ripeness. However the magnitude of decline is cultivar dependent. Generally, when fruits are harvested at matured green stage, the pulp pH is high but as ripening progresses pH drops. Thus the pulp pH could be used as an index of ripening (Dadzie *et al.*, 1997).

2.3 Pineapple

Pineapple (*Ananas comosus*) is an important food crop planted extensively in tropical and subtropical regions. The Malaysian pineapple industry became the third biggest pineapple producer in the 1960s and early 1970s (Chan, 2000). The production levels were 150,000 metric tons over the last 10 years. The pineapple cultivars are classified into five groups: Cayenne, Queen, Spanish, Brazilian and Maipure. Josapine is one of the most popular pineapple varieties in Malaysia. The Josapine variety, a product of a research work conducted by the Malaysian Agriculture Research and Development Institute, is a hybrid between the "Johor" variety and the "Sarawak" variety.

The pineapple is a composite, non-climacteric fruit that shows moderate to low rates of respiration and ethylene production (Biale *et al.*, 1981). In addition, it has low sensitivity to ethylene. Pineapple does produce ethylene gas but the amount is relatively low compared to banana (moderate), apple (high) and passion fruit (very high). When ethylene levels ranging from 0.01 to 1000 μL/L were applied to stage 4

fruits (fruit just at the start of ripening) no respiration or chemical changes were induced which could be interpreted as affecting the ripening processes. This proves that pineapple is a non-climacteric fruit (Dull *et al.*, 1967).

Since its non-climacteric characteristic, pineapple should not be cut before ripening begins if a good flavour and quality are to develop. The pulp generally only reaches its full flavour if the fruit is left to ripen on the plant and is usually harvested while still firm (two-thirds ripe).

Nonetheless, pineapple can ripen after harvest, but it requires certain temperatures for this process to occur. In most varieties, the degree of ripeness of the fruit is clear from the yellowness of the skin. However, a pineapple may be fully ripe while still green on the outside. If one of the inner crown leaves can be pulled out easily, the pineapple is fully ripe. Pineapple intended for shipping is harvested when green, while that intended for immediate eating is harvested in the semi-ripe state and that intended for canning in the ripe state.

Like bananas, they are chill-sensitive and should not be stored in the refrigerator. In a study in South Africa, the most suitable storage temperature for Queen (harvested at 50-80% yellow and less than 10% sugar content) was 14˚C, with no chilling injury occurring in storage at about 12˚C. Queen pineapples stored at 2 or 4˚C developed a white, watery pulp while fruit stored at higher temperatures developed internal browning (van Lelyveld *et al.*, 1991). Storage at 3 and 8˚C for longer than 2 weeks resulted in the crown and shell appearance being unacceptable (Paul *et al.*, 1985). At room temperature of 20˚C and 60% RH, they could be kept for only about 3 days (Mercantilia, 1989). As reviewed by Thompson (2003), some storage recommendations for pineapples are as follows:

- 7-13˚C and 85-90% RH for 2-4 weeks (Mc Gregor, 1989)

- 10°C and 90% RH for 2-4 weeks for green fruit (Anon, 1967)
- 4.5-7°C and 90% RH for 2-4 weeks for ripe fruit (Anon, 1967)
- 7°C for at least 7 days (Smith 1983)
- 10-13°C and 90% RH for 3-4 weeks for mature green fruit (Snowdon, 1990)
- 7-10°C and 90% RH for 3-4 weeks for turning fruit (Snowdon, 1990)
- 7°C and 90% RH for 2-4 weeks for ripe fruit (Snowdon, 1990)

2.4 Ethylene and ripening of fruits

Ethylene is a plant hormone that differs from other plant hormones in being a gas. It has the molecular structure: $H_2C=CH_2$. When fruits approach maturity, they release ethylene. Ethylene promotes the ripening of fruit (Abeles *et al.*, 1992). Among the many changes that ethylene causes is the destruction of chlorophyll. With the breakdown of chlorophyll, the red and/ or yellow pigments in the cells of the fruit are unmasked and the fruit assumes its ripened colour.

Ethylene is commercially used to trigger ripening is some crops, such as bananas and avocados. The application of ethylene at a controlled rate means that these products can be presented to the customer as "ready to eat". For avocados this is a significant benefit as the consumer can now purchase an avocado to eat that night rather than buying a hard fruit that may take several days to ripen. The concentration of ethylene required for the ripening of different products varies. The concentration applied is within the range of 1 and 100 μL/L. The time and temperature of treatment

also influences the rate of ripening with fruit being ripened at temperatures between 15 and 21 °C and relative humidity of 85 – 90 % (Jobling, 2000).

The common practice of placing a tomato, avocado or banana in a paper bag together with fruits that are intended to be ripened is an example of the action of ethylene produced by ripe fruit to hasten the ripening of those which are kept together. Increased levels of ethylene contained within the bag, released by the produce itself, serves as a stimulant after re-absorption to initiate the production of more ethylene. The overall effect would be ripening, aging and eventually spoilage (Abeles, 1992).

Researchers showed that the ethylene treated fruit was equivalent in quality and healthfulness to naturally ripened fruit (Chace, 1934). This is mainly because of the fruit has already achieved its physiological maturity before it can respond to the external ethylene and the ripening changes triggered by ethylene are essentially the same between the artificially and naturally ripened fruits. According to Clendennen *et al.* (1997), these changes include changes in starch and sugar content, acidity and concentration of pectic substances. Immature fruit will not respond properly to ethylene (Abeles, 1992). Nevertheless, there have been no consistent studies showing any difference in flavour between ripened with and without ethylene (Watada, 1986; Scriven *et al.*, 1989). In addition, there is no clear and consistent evidence indicating that the artificially ripened fruit has any more or less nutritive value than naturally ripened fruit (Abeles, 1992).

There are two classes of fresh produce in terms of ethylene production. There are climacteric products, mainly fruit that produce a burst of ethylene as they ripen, as well an increase in respiration and there are the non-climacteric products that do not increase ethylene production when they ripen (Biale *et al*, 1981).

2.4.1 Climacteric fruits

Respiration rate of fruits increases to a maximum just prior to full ripening and those fruits that exhibits this increase in respiratory rate along with ethylene evolution just prior to senescence are called climacteric fruits. In climacteric fruits, ethylene (C_2H_4) is produced at different rates based on the stage of fruit development. The fruits are characterized by a low ethylene production during the pre-climacteric period (unripe or green fruit), followed by a climacteric phase where a sudden increase in the ethylene production takes place during ripening, a phenomenon called autocatalytic C_2H_4 production (Abeles, 1992). This rise in ethylene concentration is considered the main factor for the ripening of fruits such as banana, avocado, tomato and melon (Bower *et al.*, 2002). After this step, the C_2H_4 production decreases considerably and the respiratory activity declines gradually in the post-climacteric phase and this phase is also known as senescence (Yang *et al.*, 1984). Thus, the post-harvest physiology is characterized by the pre-climacteric phase, followed by a sudden increase in the ethylene production, signaling the beginning of ripening, and it is represented by a strong rise in the respiration activity (Palomer *et al.*, 2005). Some modifications occur during ripening which include changes in peel color and pulp texture, conversion of starch into sugar, reduction of polyphenols and synthesis of aromatic compounds and others (Clendennen *et al.*, 1997).

Besides produce larger quantity of ethylene in association with their ripening, exposure of climacteric fruits to ethylene treatment results in faster and more uniform ripening. Thus, these fruits can be ripened after harvest. The followings are examples of climacteric fruit; apple, pear, peach, plum, kiwifruit, avocado, banana, plantain, mango, papaya, sapodila, guava and passion fruit. In the case of vegetables, the

climacteric rise in respiration as is observed in certain fruits is not apparent (Biale *et al.*, 1981; Kader, 1992).

2.4.2 Non-climacteric fruits

Respiration rate of some fruits does not accelerate after harvest and these fruits are the best when ripened before harvest and are grouped as non-climacteric. In non-climacteric fruits, a steady fall in respiratory activity occurs. These fruits are not capable of continuing their ripening process once removed from plant. They will soften a little, lose green colour and develop rots as they become old but they do not change to improve their eating characteristics. Non-climacteric fruits produce very small quantity of ethylene and do not respond to ethylene treatment, except in terms of degreening in citrus fruits and pineapple. The examples of non-climacteric fruits include strawberry, citrus fruits (grapefruit, lemon, lime, orange and mandarin orange), pineapple, pomegranate and litchi (Biale *et al.*, 1981, Kader 1992).

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

3.1.1 Collection of materials

50 kg of fresh banana fruits of the Berangan variety at maturity stage 1 were purchased from an orchad in Bidor, Perak. Pineapples of the variety of Josapine at maturity stage 4 were collected from a pineapple field in Bachok, Kelantan. The amount of the pineapple was 50 kg and they were selected for uniformity in weight (1±0.1 kg). All the fruits were selected for the absence of defects.

Boxes with lid were obtained from a supplier in Kuala Terengganu. The size of the boxes was (43 cm x 25 cm x 27 cm, L x W x H) and total of 34 boxes were used during the experiment.

3.1.2 Preparation of fruits

Bananas were de-handed and the pineapples were removed their air suckers. All fruits were washed in water containing sodium hypochlorite (Chlorox^{TM}) solution to remove dirt and kill any microbes or spores on the fruits surface. The sodium

hypochlorite used was in 0.5% concentration. The fruits were then left to air dried before they were sorted out in terms of uniformity in maturity stage as well as absence of blemishes and disease symptoms.

3.2 Methodology

3.2.1 Mixed loading and storage

Four treatments with three replications were done in the study where each treatment with different weight ratio between banana and pineapple as indicated in Table 3.1.

Table 3.1: Weight ratio of banana and pineapple for each treatment

Treatments	Banana : Pineapple (kg)
T_0 (Control)	1: 0
T_1	1: 1
T_2	1: 2
T_3	1: 3

The bananas were weighed using top-pan balance in order to obtain 1±0.1kg of bananas for each box. All the boxes (34 boxes) were arranged with 1kg of banana. Among these boxes, 13 boxes were filled with 1kg of pineapple and another 9 boxes were arranged with 2kg of pineapples in each box. Another 6 boxes of banana were then kept together with 3kg of pineapples in each box. The remaining 6 boxes of banana were not packed with any pineapple and acted as control. All the fruits were

arranged into boxes randomly and all the boxes were kept in temperature 13±1°C for twelve days.

3.2.2 Sampling of fruit for analysis

There were two major sample analyses which were physical and chemical analyses. Three banana samples from each replication of each treatment were randomly drawn out for assessment every three days. The parameters that were analysed include peel colour, firmness, percentage of weight loss, starch content and total soluble solids (TSS).

For pineapple, a sample of pineapple was taken from each replication to be assessed for peel colour, firmness and total soluble solids (TSS) every three days. The Table 3.2 and Table 3.3 detail out the replication of the whole analysis for banana and pineapple respectively.

Table 3.2: Analyses replication for banana

Treatments / Parameters	Control (1: 0)	1: 1	1: 2	1: 3
Peel Colour	3uv	3uv	3uv	3uv
Pulp Firmness	3uv	3uv	3uv	3uv
Weight Loss	3w	3w	3w	3w
Starch Content	3w	3w	3w	3w
TSS Content	3w	3w	3w	3w

Notes: u: 3 readings/sample
v: 3 samples/replicate
w: 3 readings/replicate

Table 3.3: Analyses replication for pineapple

Treatments / Parameters	1:1	1: 2	1: 3
Peel Colour	3x	3x	3x
Pulp Firmness	3y	3y	3y
TSS Content	3z	3z	3z

Notes: x: 5 readings/replicate
y: 4 readings/replicate
z: 3 readings/replicate

3.2.2.1 Peel colour

Peel colour changes were determined using a Konica Minolta Chroma-Meter. Colour measurements were recorded using Hunter L*, a* and b* scale (Hunter, 1975; Francis, 1980). The "L" coordinate is a measure of lightness (white - black and ranges from no reflection L=0 to perfect diffuse reflection L=100), the "a" scale ranges from negative values for green to positive values for red and the "b" scale ranges from negative values for blue to positive values for yellow.

3.2.2.2 Firmness

Firmness was measured using the Stable Macro System, TA.XTplus texture analyzer. The probe needle used was P2N and the parameters of the test were as follow:

Pre-test speed : 1.0mm/s

Test speed : 0.5mm/s

Post test speed: 3.0mm/s

Distance : 10mm

Trigger force : Auto (5g)

The samples were carefully positioned on the stage of the texture analyzer. The maximum positive force (firmness) required for the pulp to yield to the tip of the probe was recorded.

3.2.2.3 Percentage of weight loss

The samples were weighed individually using a top-pan balance and the weight of each sample was recorded. The percentage of weight loss for each sample was calculated based on the following formula:

$$\text{Percentage of weight loss} = \frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \times 100\%$$

3.2.2.4 Starch content

Starch iodine test was carried out to measure the starch content for each banana sample using iodine in potassium iodide solution. The sample was cut longitudinally into halves and the cut surface was then dipped in iodine solution for 20 seconds. The stain patterns were rated based on their estimated percentage of starch from the colour reaction.

3.2.2.5 Total soluble solids (TSS) content

TSS was measured using hand-held refractometer (Atago, MODEL REF 103). The samples were cut into small pieces and put in a muslin cloth and then squeezed to get the juice. The refractometer prism was first cleaned well with distilled water and wiped dry. One or two drops of juice were put on the refractometer prism and the reading which is expressed as degrees of Brix was recorded. Before measuring the next sample, the refractometer prism was cleaned well.

3.3 Statistical analysis

The experimental design for this study was Complete Randomized Design (CRD). Data obtained from the experiment was statistically analyzed using one-way analysis of variance (ANOVA) followed by a Tukey multiple comparisons test at a significant level of $p< 0.05$using Minitab Release 14 statistical programme.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Physical and chemical changes in banana

4.1.1 Peel colour

The stage of ripening of banana, cooking banana and plantains has been closely linked with the changes in peel colour (Loesecke, 1950; Palmer, 1971). The disappearance or loss of peel green colour and the corresponding increase in yellowing of the peel during ripening are the obvious manifestation of in banana. The loss of green colour is due to the degradation of the chlorophyll structure. External changes in peel colour during ripening often reflect changes in pulp colour (Wainwright *et al.*, 1990).

L* value is a measure of lightness of the fruit surface (Ranganna, 1986). As the ripening progresses, the lightness will increase as the skin changes from dark green colour to light green and then yellow. Figure 4.1 indicates that lightness for the bananas from control and treatment of 1:2 increased from day 0 to day 12.

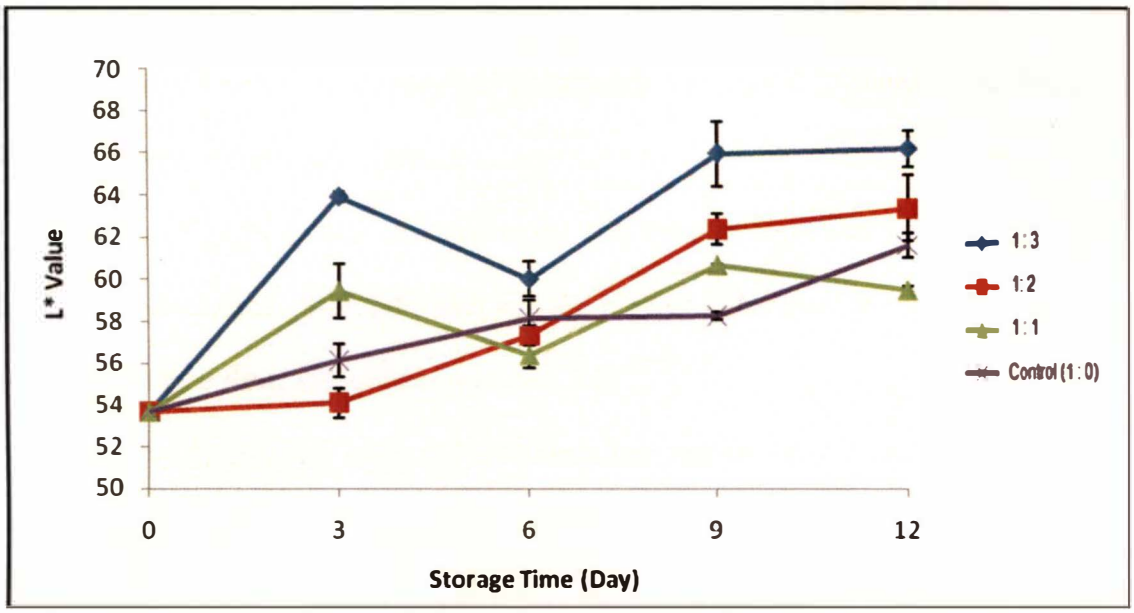

Figure 4.1: L* value of bananas in different ratios of mixed loading with pineapple during storage at 13±1C°

A significant increase ($p<0.05$) in lightness from day 6 to day 9 had occurred on the sample of 1:2 treatment. For the bananas from treatment 1:3, they generally increased in their lightness across the storage time, except on day 6, when there was a decrease in the lightness before the lightness increase again on day 9. The presence of blackish spots on the skin surface of some of the bananas might affect the lightness and resulted in the decrease of lightness on that day. The lightness of the bananas from this treatment increased significantly ($p<0.05$) from day 0 to day 3.

Bananas from treatment of 1:1 did not show a gradual increase from day to day as there was a decrease on day 6 and day 12. Similarly, the decrease was contributed by the blackish spots on the surface. For this treatment, significant changes ($p<0.05$) in lightness occurred on day 9.

On day 3, bananas from 1:3 treatment had significantly higher ($p<0.05$) L* value than other treatments and control sample. The L* value was then followed by bananas from treatment of 1:1, control and finally treatment of 1:2. This could be

suggested that the onset of ripening before that day had caused the bananas to change form dark green to light green colour.

On day 6, there was no significant different in lightness between all the treatments and control. Still, L* value was the highest in bananas from 1:3 treatment, followed by those from 1:2, control and then 1:1.

On day 9, bananas from 1:3 treatment had significantly higher ($p<0.05$) L* value than those from treatment of 1:1 as well as control. There was no significant difference between treatment 1:3 and 1:2 as the bananas from 1:2 had been initiated their ripening after day 6, thus, their dark green skin had changed into light green skin.

On day 12, there was no significant different between treatment of 1:3, 1:2 and control sample. This might be due to the reason that the ripening process for control had been induced as well after day 9 besides those from treatment 1:3 and 1:2 which had been initiated the ripening earlier. However, bananas from treatment of 1:3 were significantly higher ($p<0.05$) than those from treatment of 1:1. As discussed earlier, the low lightness of bananas from 1:1 treatment was due to the blackish spots on some of their surface.

According to Ranganna (1986), a* represent the green to red spectrum. In other words, a* scale range from negative values for green to positive values for red. As ripening progresses, a* value will gradually increase from negative value to positive value due to the loss of green colour as a result of the degradation of the chlorophyll structure (Wainwright *et al.*, 1990). As indicated in Figure 4.2, a* value for bananas from all treatments and control samples increased along with the storage time.

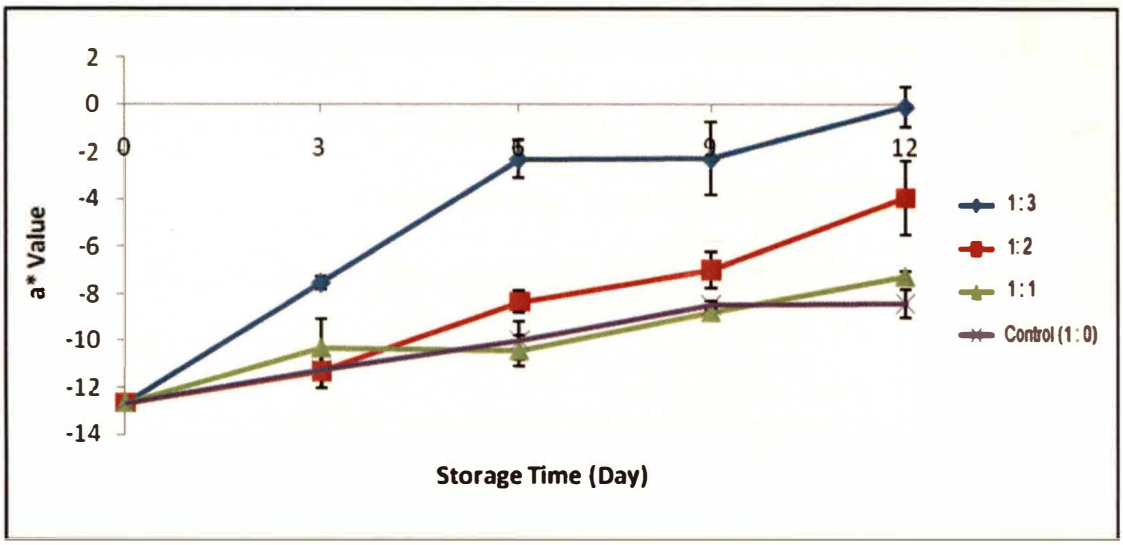

Figure 4.2: a* value of bananas in different ratios of mixed loading with pineapple during storage at 13±1C°

However, for control samples and bananas from treatment of 1:1, the increase in a* value did not exhibited significant changes ($p>0.05$) (Appendix E) from day 0 to day 12. For treatment of 1:2, the bananas only showed significant higher ($p<0.05$) a* value on day 12 than day 0, whereas for treatment of 1:3, the bananas showed significant higher ($p<0.05$) a* value on day 6 than day 0.

The results imply that there was no significant loss of green colour for control samples and bananas from treatment 1:1 throughout the storage period. While for treatment 1:2 and 1:3, the loss of green colour was apparent on day 12 and day 6 respectively. Although the changes in peel colour is closely related to the ripening of the banana (Loesecke, 1950; Palmer, 1971), fruits could retain their green peel colour even though ripening has already commenced internally creating a situation whereby the peel colour does not really reflect the internal changes, as reviewed by Dadzie *et al* (1986).

On day 3, 9 and 12, there was no significant different in a* value for all the treatments and control. However, absence of significant different between treatments in a* value could not really imply that there was no significant different in the internal

changes caused by the ripening. For treatment of 1:3, two samples which still remained green while others from the same treatment had turned fully yellow on day 12 might cause the mean a* value of this treatment to become lower. This then resulted in the absence of significant difference between it and other treatments as well as control.

On day 6, bananas from treatment of 1:3 had significant higher ($p<0.05$) value of a*compared to those from the treatment of 1:1 and control samples. This might be resulted from the loss of green colour of the bananas from 1:3 treatment had been stimulated to occur after day 3.

In overall, a* value was the highest in the bananas from treatment of 1:3 across the storage time, followed by treatment of 1:2. For treatment of 1:1 and control, they tended to show lower a* value in comparison to 1:3 and 1:2. Thompson *et al.* (1982) reported that the sensitivity of bananas to ethylene is very low, within the range of 0.01-1.0 μL/L. Hence, larger amount of exogenous ethylene must be produced from more numbers of pineapples in order to sufficiently trigger the ripening of bananas.

b* represent the blue to yellow spectrum. In other words, b* scale range from negative values for blue to positive values for yellow (Ranganna, 1986). During ripening, the degradation of chlorophyll unmasks the carotenoid pigments lying underneath in the unripe fruit. The amount of chlorophyll will gradually decline to zero when the fruit is in fully yellow ripe stage (Von Loesecke, 1929). Figure 4.3 shows that b* value for all the treatments and control generally increased from day 0 until day 12.

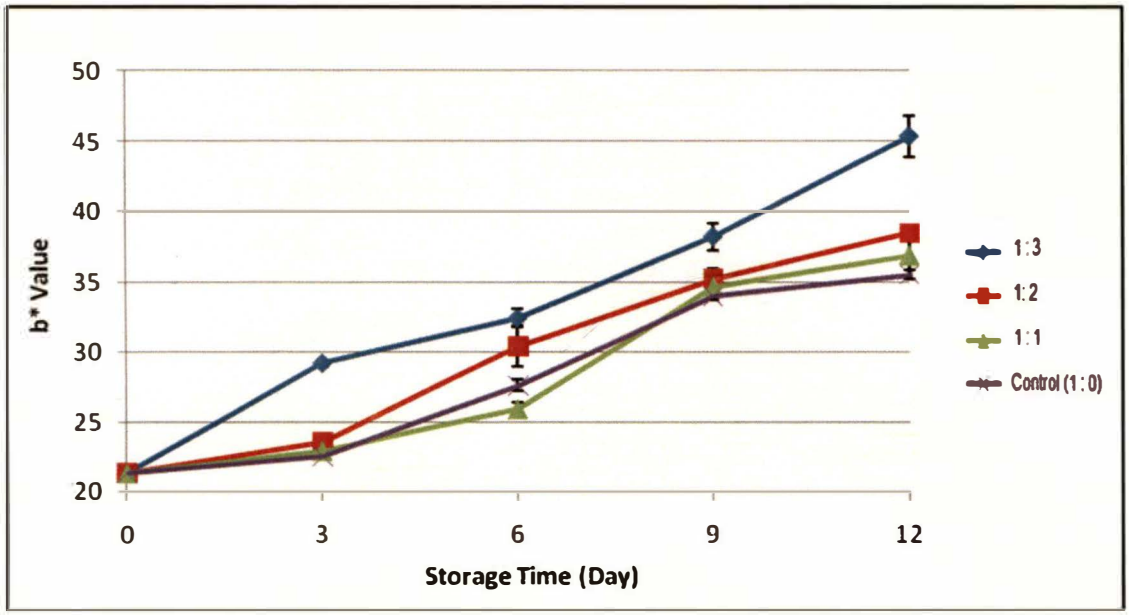

Figure 4.3: b* value of bananas in different ratios of mixed loading with pineapple during storage at 13±1C°

For control and treatment of 1:2, there was a significant increase ($p<0.05$) (Appendix F) in b* value on day 6 whereas for the treatment of 1:1, the significant increase ($p<0.05$) occurred on day 9. b* value for bananas from treatment of 1:3 increased significantly ($p<0.05$) from day 0 to day 3.

On day 3, there was a significant different ($p<0.05$) between bananas from treatment of 1:3 and those from other treatments as well as control. On day 6, day 9 and day 12, there was no significant difference between all treatments and control. Treatment of 1:3 tended to show higher b* value, followed by 1:2 while bananas from 1:1 and control tended to showed lower b* value across the storage time. The results indicate that the ripening of bananas from treatment of 1:3 was induced earliest, which was within first three days of storage, in order to unmask their yellow. Those from treatment of 1:2 were induced to significantly turn to yellow colour after day 3 while bananas from treatment of 1:1 were induced after day 6. The results imply that more amounts of pineapples should be mixed loaded with bananas in order to induce the ripening of bananas.

4.1.2 Pulp firmness

According to Smith *et al.* (1989), pulp firmness is often inversely related to ripening, implying that, as ripening progressed, pulp firmness declined. This is because bananas undergo significant textural transformation as they pass through the ripening process. The hard and green fruit turns into a yellow fruit with tender and soft internal pulp at the optimal ripening stage, and becomes mushy as it advances toward senescence.

Figure 4.4 shows that the pulp firmness of bananas of every treatment and control decreased across the storage time. One exception was observed on day 12, during which the firmness of bananas samples from the treatment of 1:1 and 1:3 was slightly higher than the firmness value on day 9. This was contributed by the reason that some of the samples from these treatments still remained tough and green on day 12.

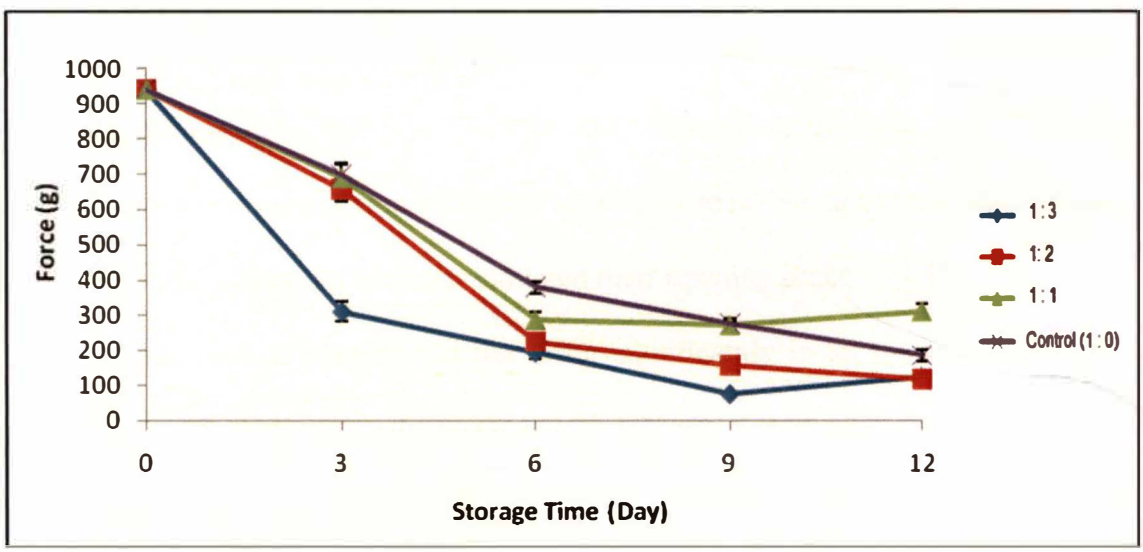

Figure 4.4: The pulp firmness of bananas in different ratios of mixed loading with pineapple during storage at 13±1C°

On day 3, bananas from the treatment of 1:3 significantly differed ($p<0.05$) (Appendix G) from the other treatments as well as control samples, with the smallest

force required to penetrate the pulp. This could be suggested that the bananas from the treatment of 1:3 underwent the most rapidly softening process due to the changes in cell wall component and degradation of starch (Seymour, 1993). The sharp decrease of their firmness on that day also indicates that the ripening of bananas from the treatment of 1:3 had been started within first three days of storage.

On day 6, bananas from the treatment of 1:3, 1:2 and 1:1 did not exhibit significant different ($p>0.05$) in their texture or firmness where bananas from 1:3 treatment were softer than those from the treatment of 1:2 and 1:1. Both the bananas from 1:3 as well as 1:2 were significantly softer ($p<0.05$) than the control samples on day 6. The sharp decrease in the firmness of bananas from the treatment of 1:2 and 1:1 on that day could be resulted from their commencement of ripening within day 3 and day 6. Due to the greater extent in the firmness reduction for treatment of 1:2, it could be suggested that the onset of ripening for bananas from 1:1 was relative slow compared to those from treatment of 1:2.

On day 9, there was no significant different between the firmness of bananas from the treatment of 1:3 and 1:2. However, they differed significantly ($p<0.05$) from those of 1:1 treatment and control samples as well. The results imply that the bananas of the 1:3 and 1:2 treatment had been initiated their ripening process earlier.

On day 12, the bananas did not differ significantly in all the treatments and control except for those from the treatment of 1:1, which had relatively firm pulp in comparison to bananas from the other treatments ($p<0.05$). As discussed earlier, the firmness value for the bananas from the treatment of 1:1 was high as some of the samples being tested still remained green and tough on that day. Absence of significant different between control and treatment of 1:3 and 1:2 might be due to the ripening of control samples had been initiated after day 9.

In overall, bananas from treatment of 1:3 tended to show the lowest pulp firmness for each day of the storage except on day 12, during which the firmness value was slightly higher than those from treatment of 1:2. In addition, the bananas from treatment of 1:3 did not show significant decrease in firmness after rapid decline in firmness on day 3. This could be suggested that the cell wall transformation and starch degradation was faster in bananas from the 1:3 treatment compared to the other treatments and much of the starch had been degraded into sugar on day 3. Thus, this could imply that the ripening of those from treatment of 1:3 was initiated before day 3.

4.1.3 Percentage of weight loss

Dadzie *et al* (1986) reviewed that during ripening, the peel of banana looses water both to the atmosphere and to the pulp. Generally, as shown in Figure 4.5, the percentage of weight loss for the bananas from all the treatments and control increased as the storage time increased. The decline in weight loss could be due to the extent of water loss from the peel to the atmosphere was relatively high in comparison to that to the pulp as the ripening proceeded.

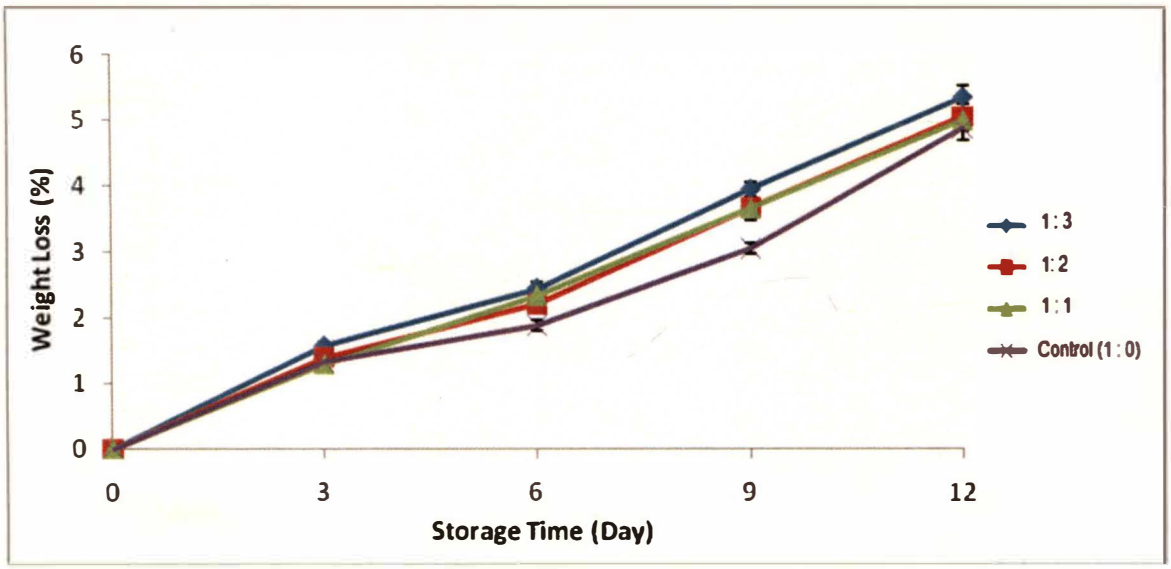

Figure 4.5: The percentage of weight loss of bananas in different ratios of mixed loading with pineapple during storage at 13±1C°

There was no significant different ($p>0.05$) (Appendix H) between all the treatments and control samples in percentage of weight loss throughout the storage period. Figure 4.1 indicates that treatment of 1:3 possessed higher percentage of weight loss followed by 1:2 and 1:1, both of which had almost the same percenatge of weight loss. For the control sample (1:0), the weight loss was relatively low most of the time. This implies that the ripening of the 1:3 was faster compared to the others although they did not significantly differ.

4.1.4 Starch content

As the banana ripens, starch accumulated by the fruit during growth and maturation is converted to sugars, which are responsible for the sweetening of the fruit as it ripens (Loesecke, 1950, Palmer, 1971). Figure 4.6 shows that the starch content of the bananas from all the treatments and control generally decreased across the storage time.

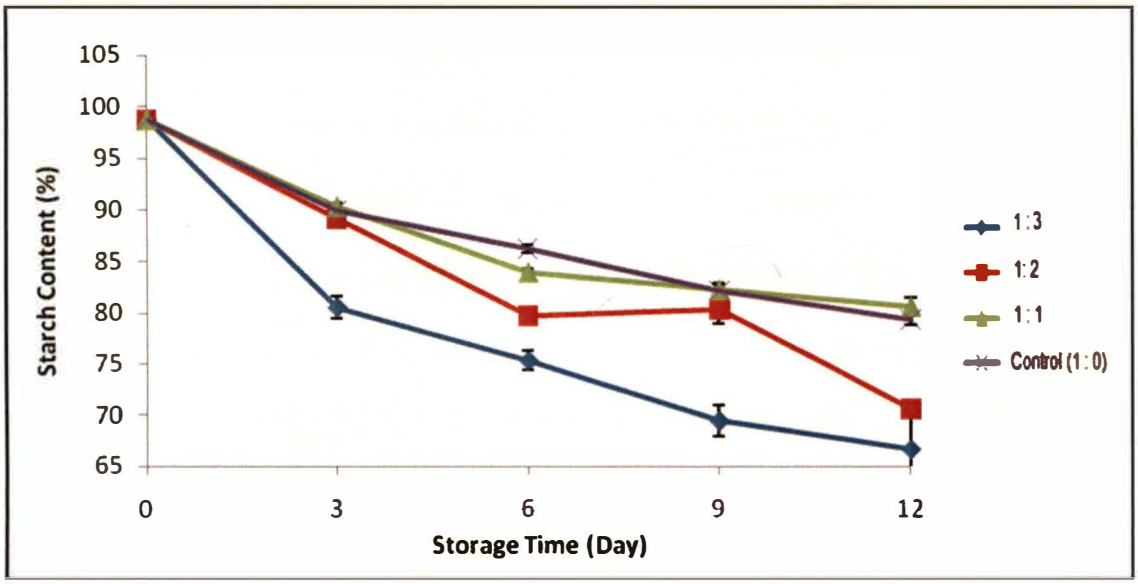

Figure 4.6: The starch content of bananas in different ratios of mixed loading with pineapple during storage at 13±1C°

The starch content for the bananas from the treatment of 1:3 declined sharply from day 0 to day 3 and this made their starch content significantly lower ($p<0.05$) (Appendix I) than the other treatments and control samples. This implies that the amount of starch that had been degraded was relatively high compared to that of bananas form the other three treatments as the onset of the ripening of bananas from treatment 1:3 had been induced before that day.

Both the bananas from the 1:3 as well as 1:2 treatments contained significantly lower ($p<0.05$) starch content than bananas from 1:1 (banana: pineapple) treatment and control on day 6. The amount of starch was the least in those from the treatment of 1:3, followed by samples from 1:2, 1:1 and finally the control samples. Absence of significant difference between 1:3 and 1:2 could be resulted from the ripening of bananas from 1:2 treatment had been started after day 3.

On day 9, similarly, the amount of starch was the lowest in those from the treatment of 1:3, followed by samples from 1:2, 1:1 and finally the control samples. The significant different ($p<0.05$) of starch content between the bananas from

treatment of 1:3 and the other treatments and control indicated that the degradation of starch in the bananas from 1:3 treatment was more rapidly because the ripening of these bananas was induced earlier than that from the other three treatments.

On day 12, bananas from the treatment of 1:3 was again the lowest in starch content, followed by those from the treatment of 1:2, control sample, and lastly the treatment of 1:1. Nevertheless, they did not exhibit significant difference in their starch content on that day. On day 12, the mean value for the starch content of bananas from treatment of 1:3 was greatly affected by the presence of two banana samples which still remained green. The percentage of starch for these two bananas was much more higher compared to the samples from the same treatment, thus, the mean value increased.

Similar to the firmness of the bananas, the starch content was the lowest in those from 1:3 treatment and was subsequently followed by the treatment of 1:2 throughout the storage period. For the bananas from 1:1treatment and control, they possessed higher starch content and they did not differ much to each other. This could be suggested that the ripening process was initiated faster when bananas were stored with more amounts of pineapples.

4.1.5 Total soluble solids content

According to Lii *et al.* (1982), starch will change to sugar during the ripening of bananas. In most ripe fruits, including banana, sugar forms the main component of soluble solids. Since the amount of sugar in bananas usually increases as the fruit matures and ripens, the total soluble solids content (TSS) can be useful to indicate the

ripeness of the fruit. As shown in Figure 4.7, the TSS content increased as the storage time increased.

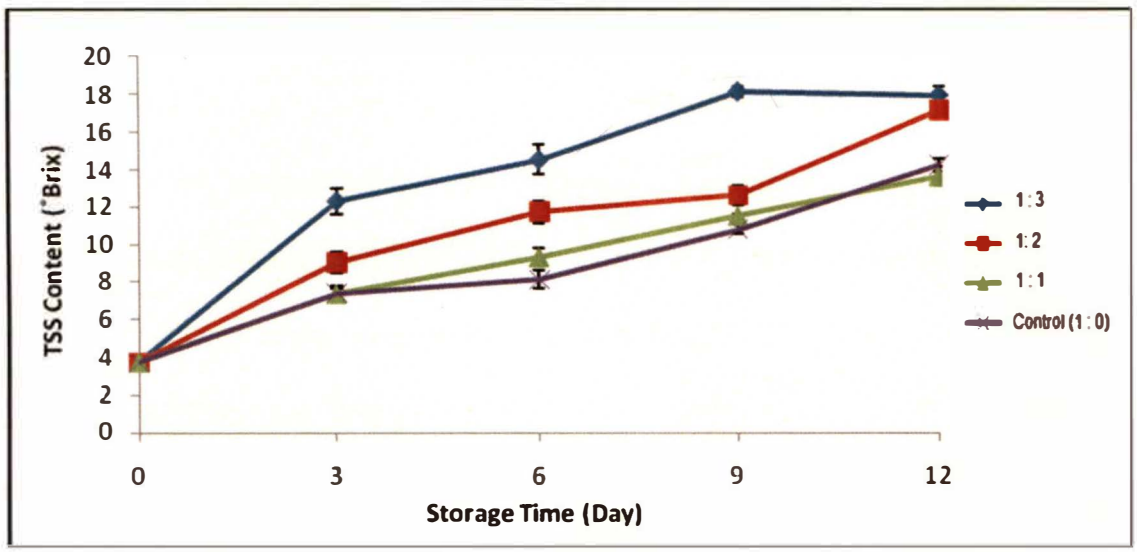

Figure 4.7: The TSS content of bananas in different ratios of mixed loading with pineapple during storage at 13±1C°

TSS for all the treatments and control samples significantly increased ($p<0.05$) (Appendix J) from day 0 to day 3. The increase of the TSS was correlated with the reduction in starch content. In other words, as more amount of starch is hydrolysed, there will be more amount of sugar being accumulated in the fruit in order to provide sweet taste to the fruit.

On day 3, 6 and 12, bananas from the treatment of 1:3 differed significantly ($p<0.05$) in TSS from those of the treatment of 1:1 as well as control samples as they had the highest TSS content. The content of TSS was followed by the samples from treatment of 1:2, 1:1 and finally the control samples, except on day 3 and day 12, during which the amount of TSS for the bananas from the 1:1 treatment was the least due to their higher starch content. Due to the sharp increase from day 0 to day 3 for the TSS content of bananas from treatment of 1:3, it could imply that their ripening had been triggered to occur before day 3.

Absence of significant different between treatment of 1:3 and 1:2 on day 3, 6 as well as day 12 implies that the ripening of the bananas from 1:2 treatment was initiated within day 3 and day 6, which was earlier than that of 1:1 and control samples. The results indicate that more numbers of pineapples should be mixed loaded with the bananas so that more amount of ethylene could be released to sufficiently stimulate the production of endogenous ethylene of bananas. Increase on the ethylene concentration is considered the main factor for the ripening of fruits such as banana, avocado, tomato and melon (Bower *et al.*, 2002).

4.2 Physical and chemical changes in pineapple

4.2.1 Peel colour

Figure 4.8 shows that L* value for pineapples increased as the storage time increased. As what happened to the TSS content, there was no significant increase ($p>0.05$) (Appendix K) from day to day for treatment of 1:1 and 1:2. Nevertheless, pineapples from treatment of 1:3 increased significantly ($p<0.05$) from day 9 to day 12 because of the degreening of the skin colour to lighter orange. The lightness did not vary significantly in all treatments.

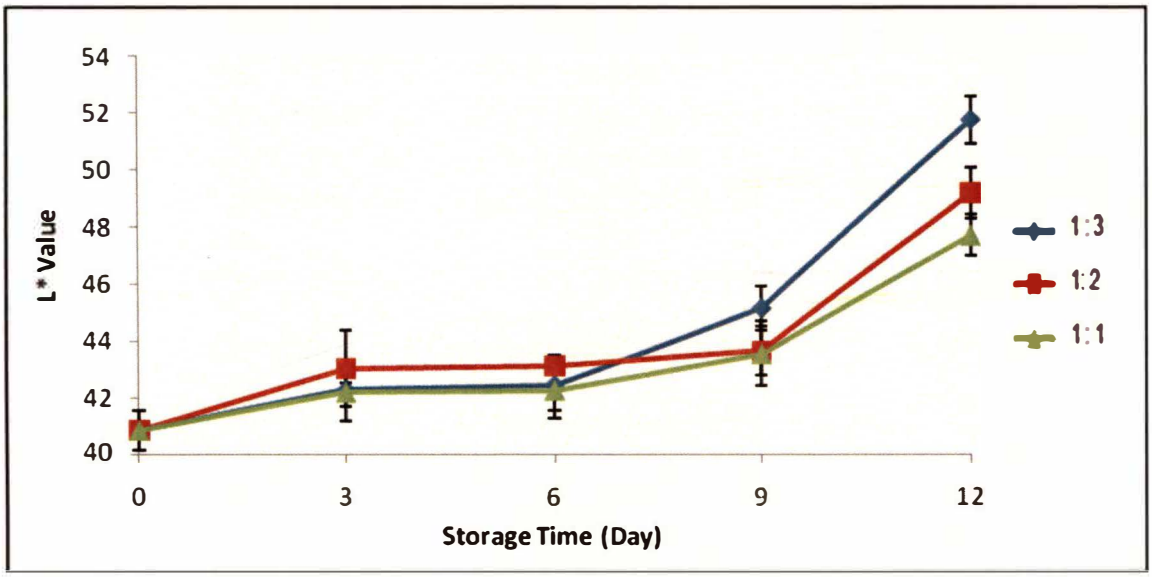

Figure 4.8: L* value of pineapples in different ratios of mixed loading with bananas during storage at 13±1C°

As degreening progresses, pineapple will change from green colour to yellow or orange colour. Increasing in a* value indicates that the fruits undergoing the loss of green colour. As indicated in Figure 4.9, a* value for all treatments increased along the storage time, with a significant increase ($p<0.05$) (Appendix L) from day 3 to day 6.

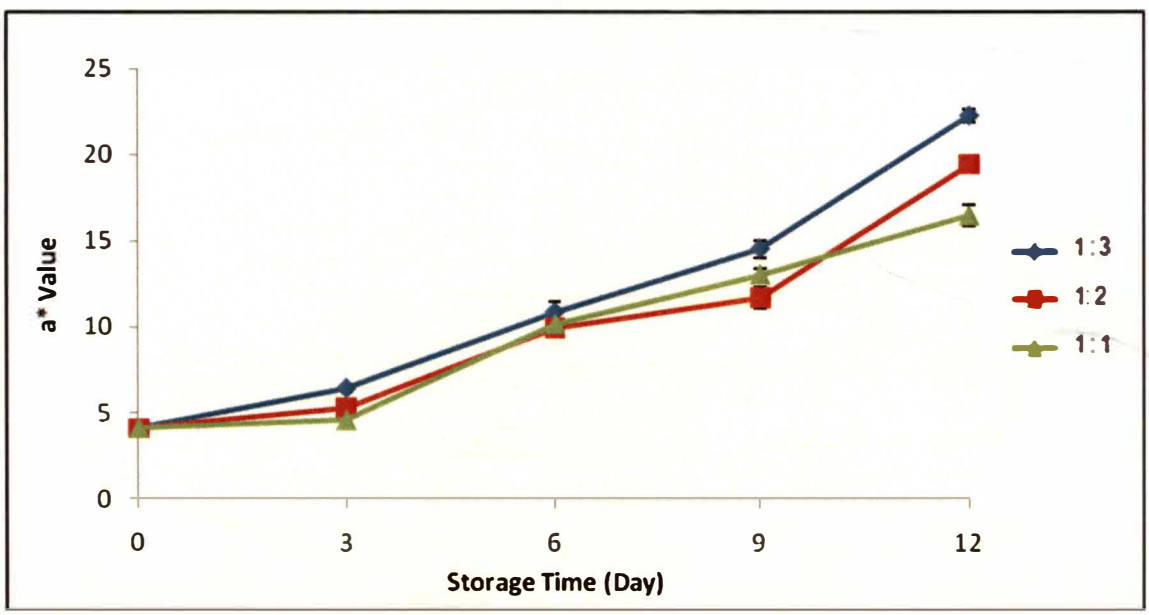

Figure 4.9: a* value of pineapples in different ratios of mixed loading with bananas during storage at 13±1C°

Generally, a* value did not differ significantly ($p>0.05$) between all the treatments, except on day 3 and day 12, when a* value for pineapples from treatment of 1:3 was significantly higher ($p<0.05$) than those from treatment of 1:1. This might be contributed by the greater amount of exogenous ethylene from ripen bananas in treatment of 1:3 which led to the more rapid degreening of the pineapples.

b* value increased during the degreening of pineapples, indicating that the fruits had turned to yellowish orange colour. Figure 4.10 shows that b* value increased with the increasing storage period. There was a significant increase ($p<0.05$) (Appendix M) from day 3 to day 6, day 6 to day 9 and lastly day 9 to day 12 as well. The continuous significant increase ($p<0.05$) imply that the pineapple continued to change their colours.

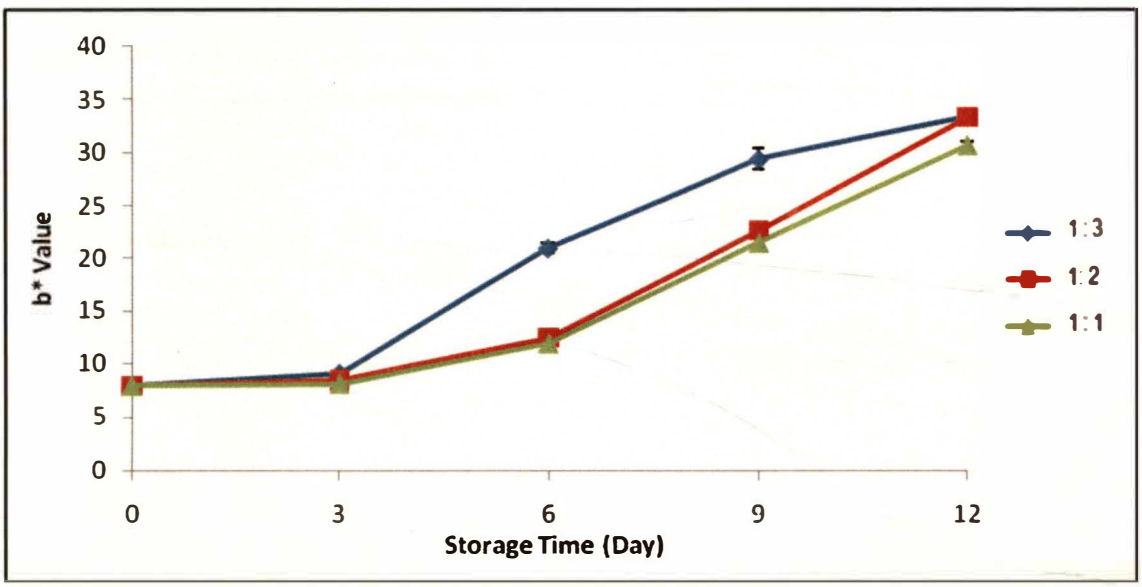

Figure 4.10: b* value of pineapples in different ratios of mixed loading with bananas during storage at 13±1C°

Basically, there was no significant different in b* value between different treatments, except on day 6 and day 9. On these two days, b* value for pineapples from treatment of 1:3 was significantly higher ($p<0.05$) than the other two. Similarly,

it might also due to the higher amount of exogenous ethylene that caused the faster degreening of the fruits in treatment of 1:3.

In overall, the colours changed from green to yellow and then orange across the storage time. Basically, the treatments did not exhibit significant different in their colours. This could be beneficial as it implies that the colour changes in pineapples did not greatly influenced by the mixed loading ratio.

4.2.2 Pulp firmness

The pulp and peel firmness of pineapples reduced with increasing storage period (Mohamed *et al.*, 1993). As shown in Figure 4.11, the pulp firmness of pineapples for all treatments declined as the storage time advanced.

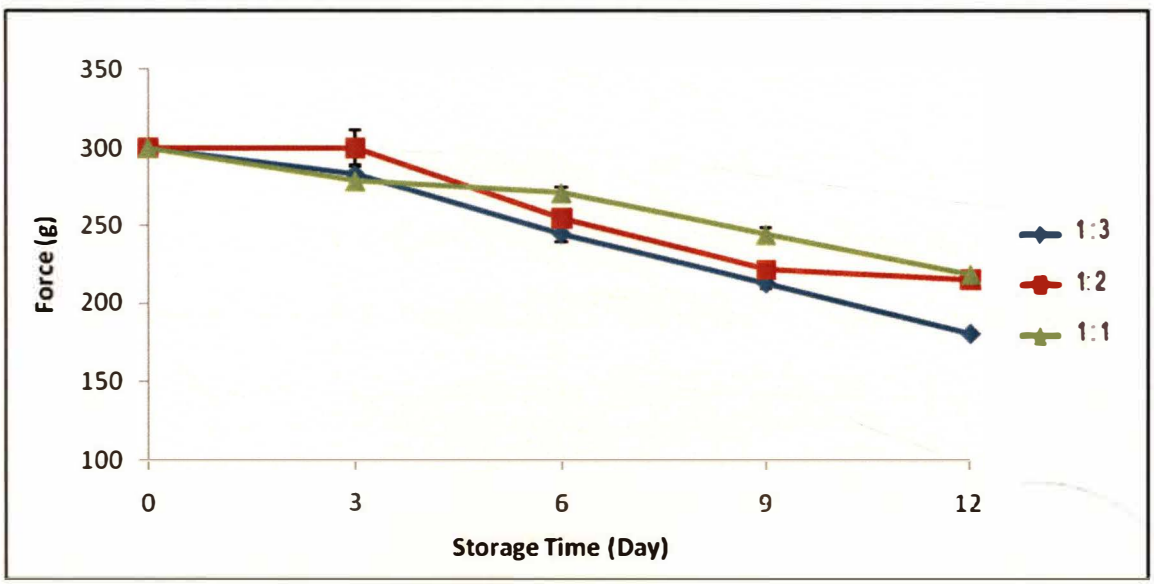

Figure 4.11: The pulp firmness of pineapples in different ratios of mixed loading with bananas during storage at 13±1C°

There was no significant decrease ($p>0.05$) (Appendix N) in the pulp firmness from day to day for pineapples from treatment of 1:1 and 1:2. This could be due to the factor that the characteristic of pineapple as a non climacteric fruit and it has low

sensitivity to ethylene (Biale *et al.*, 1981). However, when the bananas in treatment of 1:3 ripened, the ethylene released by the bananas together with exogenous ethylene generated by other fruits stored in the same cold room was enough to cause the degreening of the pineapples, which was indicated as a significant decrease ($p<0.05$) in firmness on day 6.

For each day of the assessment, there was no significant different between all the treatments except on day 9 and day 12. Pineapples from treatment of 1:3 had significant higher ($p<0.05$) firmness than those from treatment of 1:1 on day 9, whereas on day 12, they were significantly higher ($p<0.05$) than those from both the treatment of 1:2 and1:1.

4.2.3 Total soluble solids sontent

Total soluble solids (TSS) content is an indicative of the ripening or degreening of the pineapple fruit (R. Shamsudin *et al.*, 2009). The increase in TSS is related to the ripening or degreening of fruits (Samson 1986). Figure 4.12 shows that the pineapples used for mixed loading in all treatments increased in TSS across the storage period.

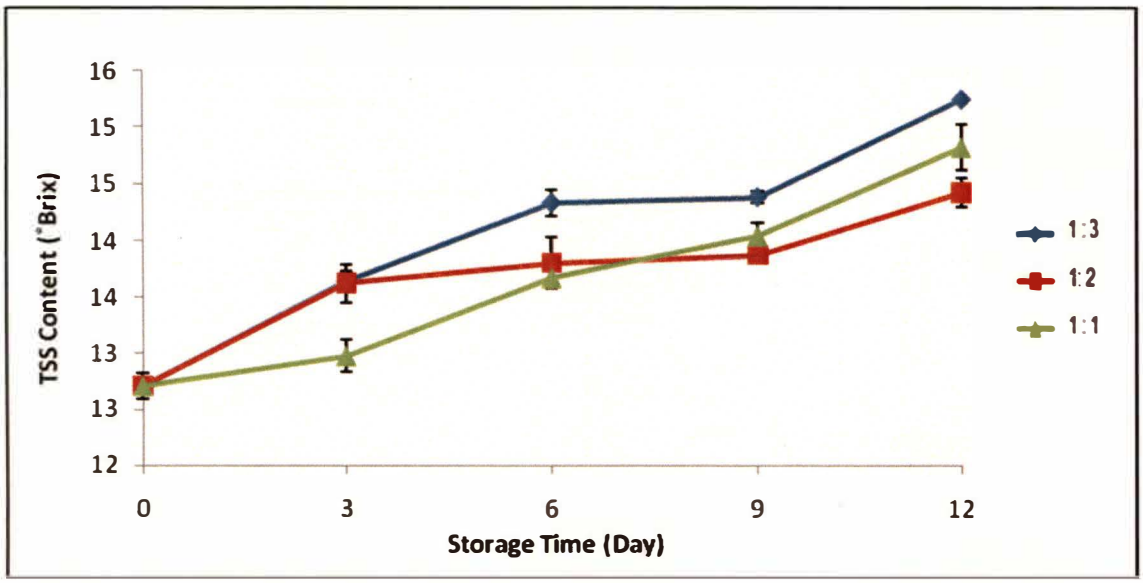

Figure 4.12: The TSS content of pineapples in different ratios of mixed loading with bananas during storage at 13±1C°

For treatment of 1:1 and 1:2, there was no significant increase ($p>0.05$) (Appendix O) in the TSS of pineapples from day to day. As discussed earlier, the amount of exogenous ethylene was not sufficient to induce the degreening of the pineapples that have low sensitivity to ethylene. However, for treatment of 1:3, a significant increase ($p<0.05$) in the TSS content was shown on day 3. This might be due to the induction of degreening by sufficeient amount of exogenous ethylene from the ripened bananas in treatment of 1:3 as well as from other fruits that stored in the same cold room.

There was no significant difference between all the treatments. This could be advantageous as it implies that there was no significant difference in the effect of different mixed loading ratios on the pineapples.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Fruit ripening is the result of a complex of changes, many of them probably occurring independently of each other (Brady, 1987). Ripening of banana will be triggered to occur when they are subjected to ethylene treatment or exposed to sufficient amount of exogenous ethylene.

When mixed loaded with pineapples at 13±1˚C, bananas from treatment of 1:3 tended to show the highest L*, a* and b* value, followed by those from 1:2 whereas the bananas from treatment of 1:1 and control obtained the relative low value throughout the storage period. In the view of colour changes, bananas from treatment of 1:3 were induced to ripe within the first three days of storage as it showed a sharp increase in yellowness on day 3, while the commencement of ripening for those from treatment of 1:2 and 1:1 occurred between day 3 and day 6, and also within day 6 and day 9 respectively.

Bananas from treatment of 1:3 exhibited significant loss in firmness and starch on day 3. In addition, their TSS content increased significantly from day 0 to day 3 as a result of the degradation of starch content. Thus, it could be suggested that the ripening of bananas mixed loaded with 3kg of pineapples was initiated before day 3 and it was the most rapidly to occur in comparison to the other treatments and control.

For the bananas from treatment of 1:2, the onset of ripening was suggested to occur within day 3 and day 6 as they showed significant changes in firmness, starch content as well as TSS content within this period of time.

For the bananas from treatment of 1:1an d control, they have significant different with those from treatment of 1:2 and 1:3 in the firmness, starch content as well as TSS content most of the storage time, implying that their ripening was induced much more slower.

In overall, the physical and chemical changes on pineapples basically did not significantly affected by the ratio of mixed loading. This could be beneficial as the mixed loading could be carried out with any desirable ratio without influencing the condition of pineapples.

Therefore, based on the results, to induce the earlier ripening onset of bananas that have low sensitivity to ethylene (Thompson *et a*l., 1982), more numbers of pineapples could be mixed loaded with them. This might be contributed by the reason that amount of exogenous ethylene sufficient to stimulate the increase production of endogenous ethylene of bananas could only be generated by more numbers of pineapples, which are a low ethylene producer. Thus, the weight ratio of mixed loading to be used for the transportation of fruits would depend on the distance or duration of the transportation. In other words, weight ratio of 1:3 could be applied for shorter duration while weight ratio of 1:2 and 1:1 can be used for longer distance transportation.

5.2 Suggestions for further study

Tan (1996) stated that it is preferable not to store different crops together. Nevertheless, from the results of this study, it could be concluded that mixed loading of banana with pineapple was successful in terms of inducing the ripening of bananas without greatly affecting the post harvest degreening of the pineapples. Thus, other combination of fruits or vegetables that are compatible in their temperature and sensitivity to ethylene can be studied as well.

It is vitally important to ensure that the storage for the crops is not mixed loaded with other produce or sources that will release exogenous ethylene as this will subsequently influence the ripening of the crops, results in ripening which is not solely due to the stimulation from the ethylene released by the mixed loaded crop.

In addition, the maturity index for the mixed loaded crop based on the colour shall be examined as well apart from evaluating the ripening using the parameters that had been used in this study. Maturity index can help to determine the time needed to reach a particular maturity stage for crop mixed loaded in different ratio, so that desirable stage can be acquired by manipulating the mixed loading ratio.

Furthermore, it will be better if the amount of ethylene produced by the pineapples in various mixed loading ratio can be quantified. This is indeed advantageous as the mixed loading ratio can be manipulated more accurately to successfully ripen the crops.

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APPENDIX A

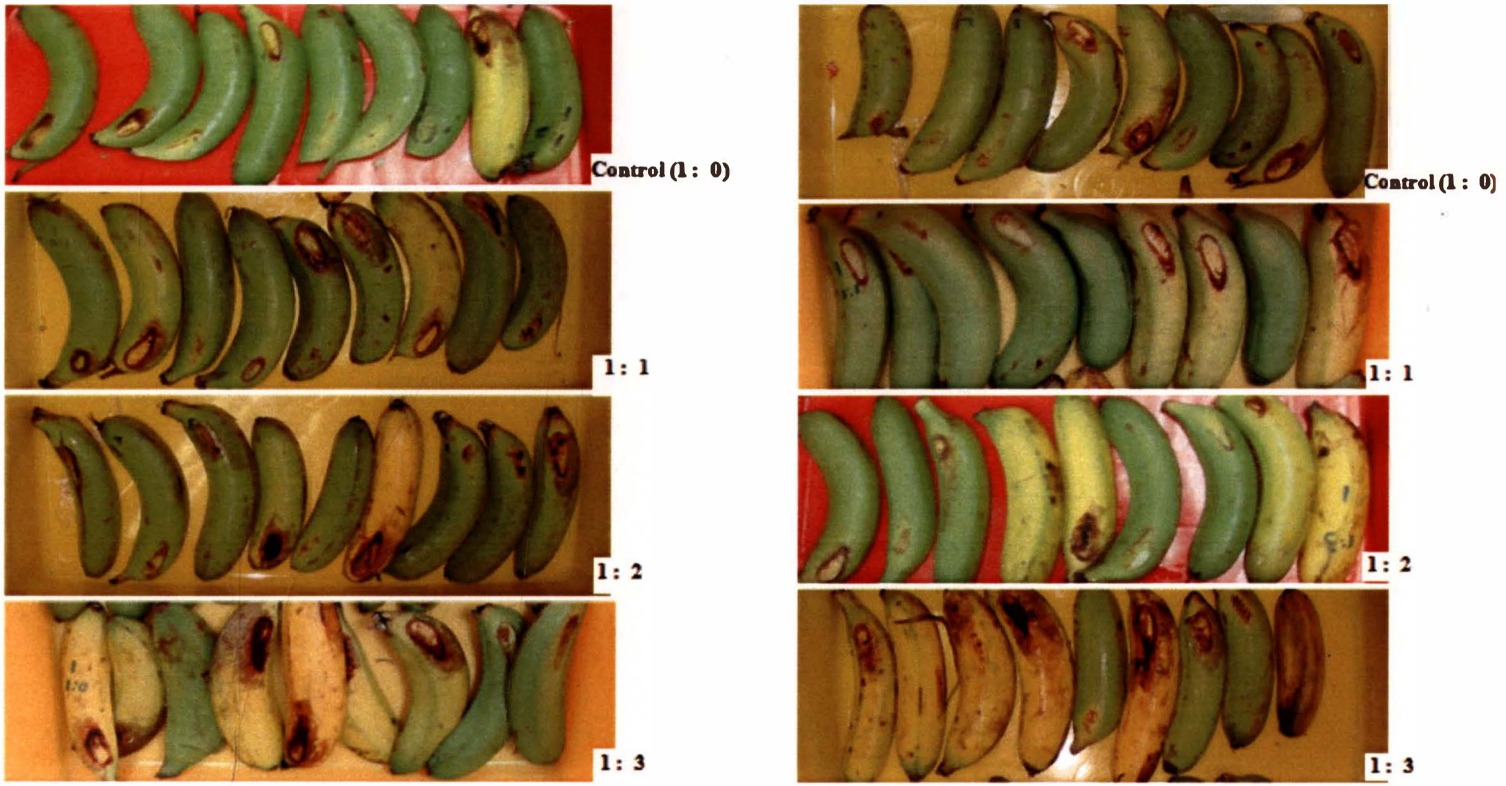
Colour of banana on day 0 and the effect of mixed loading treatments on the colour of bananas stored at 13±1˚C on day 3

Day 0

Day 3

APPENDIX B

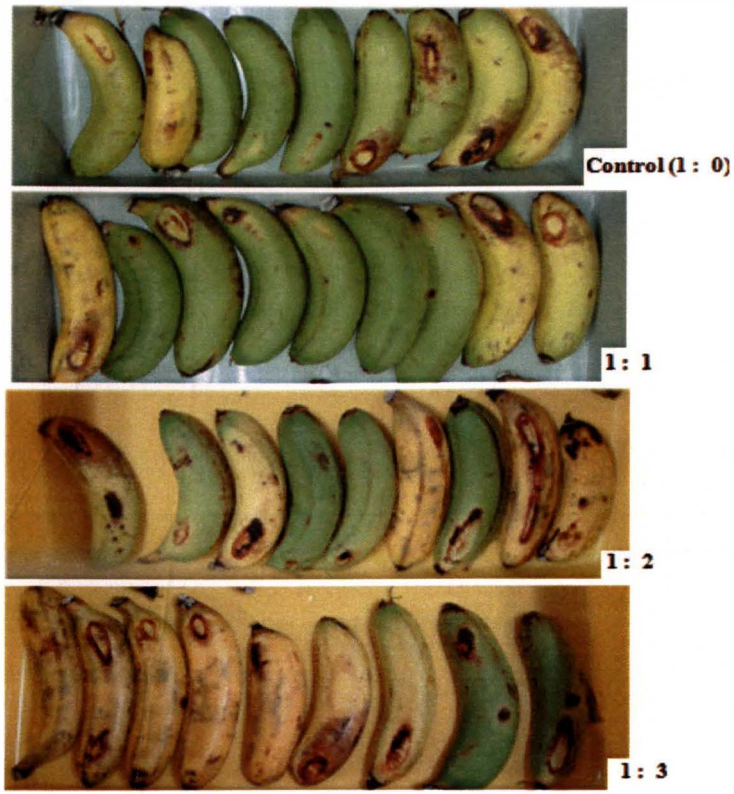
Effect of mixed loading treatments on the colour of bananas stored at 13±1°C on day 6 and day 9



Day 6 Day 9

APPENDIX C

Effect of mixed loading treatments on the colour of bananas stored at 13±1°C on day 12



Day 12

APPENDIX D

Effect of different mixed loading treatments on the L* value of bananas stored at 13±1°C

	L* Value				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control (1:0)	53.69 ± 3.09 ^{aC}	56.14 ± 4.19 ^{bcBC}	58.16 ± 4.81 ^{aB}	58.26 ± 3.63 ^{bB}	61.61 ± 5.22 ^{abA}
1:1	53.69 ± 3.09 ^{aB}	59.44 ± 4.48 ^{bAB}	56.39 ± 4.21 ^{aB}	60.66 ± 6.36 ^{bA}	59.47 ± 5.80 ^{bAB}
1:2	53.69 ± 3.09 ^{aB}	54.10 ± 5.39 ^{cB}	57.33 ± 5.71 ^{aB}	62.39 ± 5.78 ^{abA}	63.37 ± 6.94 ^{abA}
1:3	53.69 ± 3.09 ^{aC}	63.91 ± 4.90 ^{aB}	60.02 ± 6.36 ^{aAB}	65.95 ± 6.56 ^{aA}	66.16 ± 7.41 ^{aA}

Notes: Values are means of 3 replicates (3 samples/replicate; 3 readings/sample; n = 27) ± standard deviation
Lower case letters (abc) show significant difference ($p<0.05$) between treatments
Capital letters (ABC) show significant difference ($p<0.05$) between storage duration

1:0 denotes 1 kg banana stored without pineapple
1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

APPENDIX E

Effect of different mixed loading treatments on the a* value of bananas stored at 13±1°C

	a* Value				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control (1:0)	-12.67 ± 0.18 ^{aA}	-11.24 ± 2.76 ^{aA}	-10.01 ± 2.89 ^{bA}	-8.47 ± 0.62 ^{aA}	-8.40 ± 2.10 ^{aA}
1:1	-12.67 ± 0.18 ^{aA}	-10.33 ± 4.37 ^{aA}	-10.44 ± 2.20 ^{bA}	-8.79 ± 0.31 ^{aA}	-7.26 ± 0.72 ^{aA}
1:2	-12.67 ± 0.18 ^{aB}	-11.33 ± 2.41 ^{aAB}	-8.34 ± 1.57 ^{abAB}	-7.00 ± 2.60 ^{aAB}	-3.95 ± 5.46 ^{aA}
1:3	-12.67 ± 0.18 ^{aB}	-7.55 ± 0.90 ^{aAB}	-2.31 ± 2.78 ^{aA}	-2.30 ± 5.28 ^{aA}	-0.12 ± 3.02 ^{aA}

Notes: Values are means of 3 replicates (3 samples/replicate; 3 readings/sample; n = 27) ± standard deviation
Lower case letters (ab) show significant difference ($p<0.05$) between treatments
Capital letters (AB) show significant difference ($p<0.05$) between storage duration

1:0 denotes 1 kg banana stored without pineapple
1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

APPENIDX F

Effect of different mixed loading treatments on the b* value of bananas stored at 13±1˚C

	b* Value				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control (1:0)	21.35 ± 0.53 ^{aC}	22.55 ± 0.69 ^{bC}	27.63 ± 1.45 ^{aB}	34.00 ± 0.94 ^{aA}	35.54 ± 1.23 ^{bA}
1:1	21.35 ± 0.53 ^{aB}	22.95 ± 2.12 ^{bB}	25.92 ± 1.59 ^{aB}	34.69 ± 0.97 ^{aA}	36.90 ± 3.47 ^{bA}
1:2	21.35 ± 0.53 ^{aC}	23.61 ± 0.24 ^{bC}	30.45 ± 4.97 ^{aB}	35.26 ± 2.34 ^{aAB}	38.48 ± 0.97 ^{abA}
1:3	21.35 ± 0.53 ^{aC}	29.22 ± 0.76 ^{aB}	32.44 ± 2.19 ^{aB}	38.22 ± 3.32 ^{aAB}	45.29 ± 5.15 ^{aA}

Notes: Values are means of 3 replicates (3 samples/replicate; 3 readings/sample; n = 27) ± standard deviation
Lower case letters (ab) show significant difference ($p<0.05$) between treatments
Capital letters (ABC) show significant difference ($p<0.05$) between storage duration

1:0 denotes 1 kg banana stored without pineapple
1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

APPENDIX G

Effect of different mixed loading treatments on the pulp firmness of bananas stored at 13±1°C

Treatment	Firmness (Force, g)				
	Day 0	Day 3	Day 6	Day 9	Day 12
Control (1:0)	941.66 ± 95.48 ^{aA}	698.35 ± 340.8 ^{aB}	380.93 ± 175.1 ^{aC}	277.76 ± 163.7 ^{aCD}	186.23 ± 160.2 ^{bD}
1:1	941.66 ± 95.48 ^{aA}	690.24 ± 389.5 ^{aB}	287.40 ± 228.4 ^{abC}	272.17 ± 138.3 ^{aC}	311.71 ± 236.7 ^{aC}
1:2	941.66 ± 95.48 ^{aA}	656.82 ± 365.0 ^{aB}	226.43 ± 121.7 ^{bC}	158.26 ± 109.3 ^{bC}	117.42 ± 118.7 ^{bC}
1:3	941.66 ± 95.48 ^{aA}	311.65 ± 293.5 ^{bB}	196.71 ± 217.7 ^{bBC}	76.80 ± 41.0 ^{bC}	123.86 ± 150.3 ^{bC}

Notes: Values are means of 3 replicates (3 samples/replicate; 3 readings/sample; n = 27) ± standard deviation
Lower case letters (ab) show significant difference ($p<0.05$) between treatments
Capital letters (ABCD) show significant difference ($p<0.05$) between storage duration

1:0 denotes 1 kg banana stored without pineapple
1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

APPENDIX H

Effect of different mixed loading treatments on the percentage of weight loss of bananas stored at 13±1°C

	Weight Loss (%)				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
Control (1:0)	0.00 ± 0.00 ^{aD}	1.34 ± 0.27 ^{aC}	1.89 ± 0.54 ^{aC}	3.06 ± 0.52 ^{aB}	4.88 ± 1.09 ^{aA}
1:1	0.00 ± 0.00 ^{aD}	1.30 ± 0.51 ^{aC}	2.34 ± 1.00 ^{aC}	3.66 ± 1.08 ^{aB}	5.00 ± 0.97 ^{aA}
1:2	0.00 ± 0.00 ^{aE}	1.41 ± 0.32 ^{aD}	2.21 ± 0.45 ^{aC}	3.67 ± 0.73 ^{aB}	5.05 ± 1.17 ^{aA}
1:3	0.00 ± 0.00 ^{aD}	1.58 ± 0.42 ^{aC}	2.45 ± 0.60 ^{aC}	3.95 ± 0.70 ^{aB}	5.35 ± 1.11 ^{aA}

Notes: Values are means of 3 replicates (3 samples/replicate; 1 reading/sample; n = 9) ± standard deviation
Lower case letter (a) shows no significant difference ($p<0.05$) between treatments
Capital letters (ABCDE) show significant difference ($p<0.05$) between storage duration

1:0 denotes 1 kg banana stored without pineapple
1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

APPENDIX I

Effect of different mixed loading treatments on the starch content of bananas stored at 13±1°C

Treatment	Starch Content (%)				
	Day 0	Day 3	Day 6	Day 9	Day 12
Control (1:0)	98.67 ± 0.33 ^{aA}	89.89 ± 2.84 ^{aB}	86.22 ± 1.35 ^{aBC}	82.22 ± 2.55 ^{aC}	79.33 ± 1.45 ^{aC}
1:1	98.67 ± 0.33 ^{aA}	90.33 ± 1.33 ^{aB}	84.00 ± 1.20 ^{aC}	82.33 ± 1.76 ^{aC}	80.66 ± 3.22 ^{aC}
1:2	98.67 ± 0.33 ^{aA}	89.11 ± 1.35 ^{aB}	79.78 ± 3.01 ^{bC}	80.33 ± 4.81 ^{aC}	70.56 ± 2.55 ^{aD}
1:3	98.67 ± 0.33 ^{aA}	80.56 ± 3.69 ^{bB}	75.33 ± 3.22 ^{bB}	69.44 ± 5.36 ^{bB}	66.67 ± 11.67 ^{aB}

Notes: Values are means of 3 replicates (3 samples/replicate; 1 reading/sample; n = 9) ± standard deviation
Lower case letters (ab) show significant difference ($p<0.05$) between treatments
Capital letters (ABCD) show significant difference ($p<0.05$) between storage duration

1:0 denotes 1 kg banana stored without pineapple
1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

APPENDIX J

Effect of different mixed loading treatments on the total soluble solid content of bananas stored at 13 ± 1°C

Treatment	Total Soluble Solid Content (°Brix)				
	Day 0	Day 3	Day 6	Day 9	Day 12
Control (1:0)	3.73 ± 0.41^{aD}	7.40 ± 2.37^{bC}	8.11 ± 2.85^{bC}	10.79 ± 1.38^{bB}	14.24 ± 2.04^{bA}
1:1	3.73 ± 0.41^{aC}	7.36 ± 1.52^{bB}	9.31 ± 2.98^{bB}	11.51 ± 0.72^{bAB}	13.63 ± 3.18^{bA}
1:2	3.73 ± 0.41^{aD}	9.04 ± 3.45^{abC}	11.72 ± 3.50^{abBC}	12.611 ± 3.20^{bB}	17.16 ± 1.25^{abA}
1:3	3.73 ± 0.41^{aC}	12.29 ± 4.27^{aB}	14.52 ± 4.75^{aAB}	18.13 ± 1.60^{aA}	17.93 ± 2.92^{aA}

Notes: Values are means of 3 replicates (3 readings/replicate; n = 9) ± standard deviation
Lower case letters (ab) show significant difference ($p < 0.05$) between treatments
Capital letters (ABCD) show significant difference ($p<0.05$) between storage duration

1:0 denotes 1 kg banana stored without pineapple
1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

APPENIDX K

Effect of different mixed loading treatments on the L* value of pineapples stored at 13±1°C

Treatment	L* Value				
	Day 0	Day 3	Day 6	Day 9	Day 12
1:1	40.85 ± 5.35 ^{aA}	42.19 ± 7.66 ^{aA}	42.26 ± 7.55 ^{aA}	43.57 ± 8.79 ^{aA}	47.72 ± 5.63 ^{aA}
1:2	40.85 ± 5.35 ^{aB}	43.04 ± 10.60 ^{aAB}	43.15 ± 2.68 ^{aAB}	43.68 ± 6.77 ^{aAB}	49.19 ± 6.95 ^{aA}
1:3	40.85 ± 5.35 ^{aB}	42.28 ± 1.91 ^{aB}	42.46 ± 6.98^{aB}	45.17 ± 6.01 ^{aB}	51.77 ± 6.42 ^{aA}

Notes: Values are means of 3 replicates (5 readings/replicate; n = 15) ± standard deviation
Lower case letter (a) shows no significant difference ($p<0.05$) between treatments
Capital letters (AB) show significant difference ($p<0.05$) between storage duration

1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

APPENIDX L

Effect of different mixed loading treatments on the a* value of pincapples stored at 13±1°C

	a* Value				
Treatment	**Day 0**	**Day 3**	**Day 6**	**Day 9**	**Day 12**
1:1	4.08 ± 1.97 ^{aC}	4.56 ± 1.30 ^{bC}	10.17 ± 4.38 ^{aB}	13.06 ± 2.76 ^{aB}	16.49 ± 4.56 ^{bA}
1:2	4.08 ± 1.97 ^{aC}	5.25 ± 1.89 ^{abC}	9.95 ± 3.36 ^{aB}	11.70 ± 4.92 ^{aB}	19.43 ± 3.28 ^{abA}
1:3	4.08 ± 1.97 ^{aD}	6.41 ± 1.56 ^{aD}	10.88 ± 4.41 ^{aC}	14.54 ± 3.86 ^{aB}	22.22 ± 3.07 ^{aA}

Notes: Values are means of 3 replicates (5 readings/replicate; n = 15) ± standard deviation
Lower case letters (ab) show significant difference ($p<0.05$) between treatments
Capital letters (ABCD) show significant difference ($p<0.05$) between storage duration

1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

APPENIDX M

Effect of different mixed loading treatments on the b* value of pineapples stored at 13±1˚C

Treatment	b* Value				
	Day 0	Day 3	Day 6	Day 9	Day 12
1:1	7.93 ± 1.95 ^{aD}	8.13 ± 1.57 ^{aD}	11.94 ± 3.55 ^{bC}	21.42 ± 6.01 ^{bB}	30.61 ± 3.23 ^{aA}
1:2	7.93 ± 1.95 ^{aD}	8.50 ± 4.61 ^{aD}	12.48 ± 1.83 ^{bC}	22.63 ± 3.94 ^{bB}	33.28 ± 6.55 ^{aA}
1:3	7.93 ± 1.95 ^{aD}	9.05 ± 1.34 ^{aD}	20.94 ± 3.92 ^{aC}	29.33 ± 7.65 ^{aB}	33.30 ± 4.01 ^{aA}

Notes: Values are means of 3 replicates (5 readings/replicate; n = 15) ± standard deviation
Lower case letters (ab) show significant difference ($p<0.05$) between treatments
Capital letters (ABCD) show significant difference ($p<0.05$) between storage duration

1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

APPENIDX N

Effect of different mixed loading treatments on the pulp firmness of pineapples stored at 13±1°C

Treatment	Firmness (Force, g)				
	Day 0	Day 3	Day 6	Day 9	Day 12
1:1	299.91 ± 34.34 ^{aA}	278.52 ± 32.34 ^{aAB}	270.95 ± 25.86 ^{aAB}	244.30 ± 32.07 ^{aB}	218.74 ± 12.42 ^{aB}
1:2	299.91 ± 34.34 ^{aA}	299.60 ± 79.11 ^{aA}	254.55 ± 29.86 ^{aAB}	221.53 ± 30.02 ^{abB}	215.34 ± 23.52 ^{aB}
1:3	299.91 ± 34.34 ^{aA}	282.9 ± 42.19 ^{aA}	244.60 ± 33.19 ^{aB}	212.95 ± 23.27 ^{bBC}	180.76 ± 9.99 ^{bC}

Notes: Values are means of 3 replicates (4 readings/replicate; n = 12) ± standard deviation
Lower case letters (ab) show significant difference ($p<0.05$) between treatments
Capital letters (ABC) show significant difference ($p<0.05$) between storage duration

1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

APPENIDX O

Effect of different mixed loading treatments on the total soluble solids content of pineapples stored at 13±1°C

Treatment	Total Soluble Solids Content (°Brix)				
	Day 0	Day 3	Day 6	Day 9	Day 12
1:1	12.71 ± 0.70 ^{aB}	12.98 ± 0.85 ^{aB}	13.67 ± 0.50 ^{aB}	14.04 ± 0.69 ^{aAB}	14.82 ± 1.19 ^{aA}
1:2	12.71 ± 0.70 ^{aB}	13.62 ± 1.02 ^{aAB}	13.80 ± 1.35 ^{aAB}	13.87 ± 0.32 ^{aAB}	14.42 ± 0.78 ^{aA}
1:3	12.71 ± 0.70 ^{aD}	13.64 ± 0.53 ^{aC}	14.33 ± 0.67 ^{aB}	14.38 ± 0.31 ^{aB}	15.24 ± 0.20 ^{aA}

Notes: Values are means of 3 replicates (3 readings/replicate; n = 9) ± standard deviation
Lower case letter (a) shows no significant difference ($p<0.05$) between treatments
Capital letters (ABCD) show significant difference ($p<0.05$) between storage duration

1:1 denotes 1 kg banana mixed loaded with 1 kg pineapple
1:2 denotes 1 kg banana mixed loaded with 2 kg pineapple
1:3 denotes 1 kg banana mixed loaded with 3 kg pineapple

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EFFECT OF MIXED LOADING OF BANANA (MUSA PARADISIACA CV. BERANGAN) WITH PINEAPPLE (ANANAS COMOSUS CV. JOSAPINE) AT OPTIMUM STORAGE TEMPERATURE - CHIEW LAY IM