EFFECTS OF THE STORAGE TEMPERATURE AND HUMIDITY ON SHELF LIFE OF GINGER (*Zingiber officinale* ROSCOE)

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Effects of the storage temperature and humidity on shelf life of ginger (Zingiber officinale Roscoe) / Ili Mahirah Mohd Jamal.

Lihat sebelah

EFFECTS OF THE STORAGE TEMPERATURE AND HUMIDITY ON SHELF LIFE OF GINGER (*Zingiber officinale* Roscoe)

By
Ili Mahirah binti Mohd Jamal

Research Report submitted in partial fulfilment of
the requirements for the degree of
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ENDORSEMENT

The project entitled **Effects of the Storage Temperature and Humidity on Shelf Life of Ginger (*Zingiber Officinale* Roscoe)** by **Ili Mahirah binti Mohd Jamal,** Matric No. **UK16008** 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 fulfilment 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

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

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ABSTRACT

Ginger (*Zingiber officinale* Roscoe), has been used for a very long time as food ingredient, in food preservation and in pharmaceutical products. Nevertheless, the processing part has not been well researched. Ginger consists of two main constituents; ginger oleoresin and ginger oil. Ginger storage method has become necessary since this rhizome are transported worldwide for long period and not classified as perishable goods since it has the ability to stay fresh up to three months at suitable condition. This study emphasized on the importance of determining the right temperature and humidity for a simpler and more applicable storage method thus extending the commodity's shelf life. Treatments applied were storage at 5±1°C, 15±1°C, and 25±1°C with different relative humidity ranging from 75±2% to 90±2%. The parameters measured were percentage of weight loss, firmness, total colour changes, pH, total soluble solid (TSS) and water content, at weekly intervals for four weeks. The data collected from all the analyses were analyzed using the analyses of variance (ANOVA). The significant differences ($P<0.05$) between the treatments were determined using Tukey Test. After four weeks of storage, there were no significant difference among the treatments in the ginger firmness and water content where TSS, pH and weight loss showed significant difference. The lowest storage temperature and the highest relative humidity (5±1°C; 90±2%) showed the best quality retention in ginger during storage.

ABSTRAK

Halia (*Zingiber officinale* Roscoe), telah digunakan sejak dahulu sebagai ramuan dalam makanan, didalam pengawetan makanan dan didalam produk farmaseutikal. Namun begitu, dari segi pemprosesannya masih belum dikaji dengan terperinci. Halia mempunyai dua unsur penting iaitu oleoresin dan minyak halia. Kaedah penyimpanan halia telah menjadi suatu keperluan kerana halia telah diagih ke seluruh dunia dalam tempoh yang panjang dan tidak dikelaskan sebagai barangan mudah rosak kerana keupayaannya untuk kekal segar sehingga lebih daripada tiga bulan pada keadaan yang sesuai. Kajian ini menekankan kepentingan dalam menentukan suhu dan kelembapan yang sesuai untuk kaedah penyimpanan yang mudah dan boleh digunapakai, seterusnya memanjangkan jangkahayat komoditi tersebut. Rawatan yang dilakukan adalah penyimpanan pada suhu 5±1°C, 15±1°C, dan 25±1°C bersama dengan kelembapan relatif berjulat daripada 75±2% sehingga 90±2%. Parameter yang diukur adalah peratus kehilangan berat, ketegaran, perubahan warna keseluruhan, pH, jumlah pepejal terlarut (TSS) dan kandungan air pada setiap minggu selama empat minggu. Kesemua data yang terkumpul daripada semua analisis telah dianalisa menggunakan analisis bervariasi (ANOVA). Perubahan yang ketara ($P<0.05$) diantara rawatan telah ditentukan menggunakan ujian Tukey. Selepas empat minggu penyimpanan, didapati tiada perubahan yang ketara diantara kesemua rawatan didalam ketegaran halia dan kandungan air, manakala TSS, pH dan kehilangan berat menunjukkan perubahan yang ketara. Suhu yang paling rendah dan kelembapan relatif yang paling tinggi (5±1°C; 90±2%) menunjukkan kualiti halia terbaik semasa penyimpanan.

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LIST OF ABBREVIATIONS

±	plus minus
%	percent
°Brix	degree Brix
°C	degree Celsius
°F	degree Fahrenheit
ANOVA	analyses of variance
ASTA	American Spice Trade Association
BTU	British thermal unit (about 1.06 kilojoules)
CO_2	carbon dioxide
g	gram
kcal	kilocalorie
kg	kilogram
lb	pound
mg	milligram
µL	micro litre
Mt.	metric tonne
ND	not detected
ppm	part per million
RE	retinol equivalence
RH	relative humidity
SPSS	Statistical Package for the Social Sciences
TSS	total soluble solid

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CHAPTER 1

INTRODUCTION

1.1. Background of study

A popular rhizome, ginger (*Zingiber officinale* Roscoe), came from *Zingiberaceae* family and in the natural order *Zingiberales* (Kandiannan *et. al.*, 2008), had been widely used as culinary spice span since 4,400 years ago in fertile and moist soil of tropical, subtropical and Far East Asia continent which is its native region. Enormous impacts are also made by ginger as herbal medication for treating diarrhoea, nausea, arthritis, and even painful menstrual periods in Asian, Indian, Arabic and also China since ancient times.

In Malaysia, other than the rhizome used and processed commercially as fat-burner lotion, consumes as herb medication and finely blended as health beverages, the ginger are also become an important spice in most Malaysian cuisine. Ginger is an annual crop, subterranean stem (rhizome) modified for vegetative propagation and storage of food materials (Ravindran *et. al.*, 2004). The root is fleshy and fibrous, thus major in various uses. Holttum (1950) had stated that flowering is not common but seldom, if at all, flowers in Malaysia. Industrial Studies and Surveys Unit, Federal Industrial Development Authority (FELDA, 1970) had stated that 'at present, most of the ginger grown are sold as "young fresh ginger" i.e. ginger harvested four to five months after planting but some are also sold as "old ginger" i.e. ginger harvested seven to eight months after planting'. It is marketed by either scalding, to produce black ginger, or by scraping and washing to produce white ginger. It is sold in the fresh condition or, more frequently, in a peeled and split dried form (FAO, 2003)

Ginger has been used for a very long time (Lawrence and Reynolds, 1984), in terms of its uses, it is well established. Nevertheless, the processing part has not been well researched. Ginger consists of two main constituents, which are ginger oleoresin and ginger oil. This combination makes ginger an excellent remedy for digestive problems, such as flatulence, nausea, indigestion, intestinal infections and certain types of food poisoning. The combination of sweat and circulatory stimulation allows ginger to move blood to the periphery. This makes it a good remedy for high blood pressure and fever. Ginger inhibits platelet aggregation, therefore, should be the ideal condiment for people predisposed to clotting which may lead to either heart attack or stroke (Srivastava *et. al.*, 1964). Ginger is also highly effective for motion and morning sickness. Besides having medicinal properties, the ginger oil is used as an ingredient in aromatherapy candles, oils, lotion and in perfume.

1.2. Problem statement

Ginger storage method has become necessary since this rhizome are transported worldwide and transported in long period. It is not classified as perishable goods since it has ability to stay fresh up to three month in suitable condition and if the condition is very stable, ginger will be able to produce new buds with roots. In order to avoid this rhizome from producing roots and buds, or avoid them from loosing their weight due to dehydration which may cause low in market price, the ginger should be stored at suitable storage condition, with the right temperature and relative humidity.

1.3. Significant of Study

Temperature and humidity had become a critical point in commodity storage. Each produce had their critical storage condition from the plantation to the transportation period and finally to the display shelf before sold to the consumers. Mostly, produces that stored in dry and high temperature condition will result moisture loss. A moisture loss will cause loss of produce weight and a loss of weight for only 5% will made our perishable produce wilt and bring to direct loss in marketing.

This study will emphasize on the importance of determining the right temperature and humidity, with simpler and more applicable storage method for extending the commodity's shelf life. The results from the study will assist in prolonging the shelf life of ginger using the right temperature and humidity in hyper market and can also be applied by the farmers, wholesalers, retailers and also the buyers. Prolonging shelf life will increase the penetration of the crop commodity in domestic and international market (import and export) thus giving better returns for the money and energy spent.

1.4. Objective of Study

The primary objective of this study is to determine the suitable temperature and relative humidity to prolong the shelf life of ginger.

CHAPTER 2

LITERATURE REVIEW

2.1. Ginger (*Zingiber officinale* Rosc.)

Today, it is cultivated all over tropic and subtropic Asia (50% of the world's harvest is produced in India), in Brazil, Jamaica (whence the best quality is exported) and Nigeria, whose ginger is rather pungent, but lacks the fine aroma of other provenances (Arnould, 1981). Figure 2.1 (A) shows the ginger plant and Figure 2.1 (B) shows a picture of the fresh ginger rhizome. The name ginger is said to be derived from the Gingi district in India, where tea made from ginger is used for stomach upsets. Ginger is a perennial herb and grows to about 3 - 4 feet high with thick spreading tuberous rhizome.

(A) (B)

Figure 2.1: (A) The ginger plant with its flower; (B) The fresh ginger rhizome *Zingiber officinale* Rosc., with its fibrous flesh

Every year it shoots up a stalk with narrow spear-shaped leaves as well as white or yellow flowers growing directly from the root (Lawrence and Reynolds, 1984). The taxonomy of this rhizome is as follows: division, Magnoliophyta; class, Liliopsida; order, Zingiberales; family, Zingiberaceae; tribe, Zingiberaeae; and genus, *Zingiber*. Ginger originated from Southern China (Nurul, 2005) but most readings stated that this rhizome is originated from South East Asia (Anon, 2009). Some common names in Malaysia are 'halia', 'lia', 'keong' and 'jiang'. Zingiberaceae is one of the largest monocotyledonous families of the order of Zingiberales, which have been reported to be useful as food, traditional medicine, spice, condiment, dye and flavour (Halijah *et. al.*, 2000).

These are perennial aromatic herbs which form part of the undergrowth flora of tropical and sub-tropical forests with orchid like flowers. More than 150 wild and cultivated zingiberaceous species have been reported for Peninsular Malaysia and 40-50 species have been widely utilized for various purposes. In Kelantan, Selangor and Wilayah Persekutuan, Peninsular Malaysia, 16 species in seven genera are used as food, medicine, spices etc. except for *Alpina vonchigera*, which can be found in secondary forest, most are cultivated in home gardens (Halijah *et. al.*, 2000). Only three of the seven species studied that is *Alipinia conchigera, Curcuma mangga* and *Etlingera elatior* are naïve to Peninsular Malaysia (Halijah *et. al.*, 2000).

Ginger is sold worldwide and quite undistinguishable import data because of notification fresh or dried ginger. For instance, Japan is the number one importer of ginger, with 104,379 metric tons (mt.) in year 2000, and no re-export (ITC, 2002) but Japanese traditionally consume preserve ginger made from a mild fresh rhizome (Govindarajan, 1982). Between year 1996 to 2000, Malaysia had imported 19,871 mt. ginger (7,652 mt. in 2000) from China, Indonesia, Thailand and other countries, and from imported ginger in year 2000, Malaysia had re-exported 1,334 mt. to Singapore (ITC, 2002). The increasing in importation is disadvantage to Malaysian agricultural sector and economic flow because ginger is suitable to be plant in moist soil and high humidity temperature as near to equator. Even this rhizome requires long planting period, a large outcome can be obtained per plant.

2.2. The Morphology of the Ginger Rhizome

Ginger is a monocotyledonous plant belonging to the family *Zingiberaceae*. The rhizome contains both the flavor and pungency of the spice or oleoresin together with the essential oils. The main constituents of oleoresin are gingerol and shogaol (Balladin and Headley, 1997). Figure 2.3 shows a transversal section of an unpeeled ginger rhizome. The cork tissue consists of an outer zone of irregularly arranged cells and an inner zone of cells arranged in radial rows. No cork cambium is differentiated. Within the cork is a broad cortex, consisting of an outer zone flattened parenchyma and an inner zone of normal parenchyma. Cortical cells accumulate starch grains, which have marked eccentric hilums. Cortex also shows numerous oil cells with suberised walls enclosing a yellowish-brown oleoresin as. The inner cortical zone of the rhizome presents about 3 rings of collateral closed vascular bundles (Wiart and Kumar, 2000).

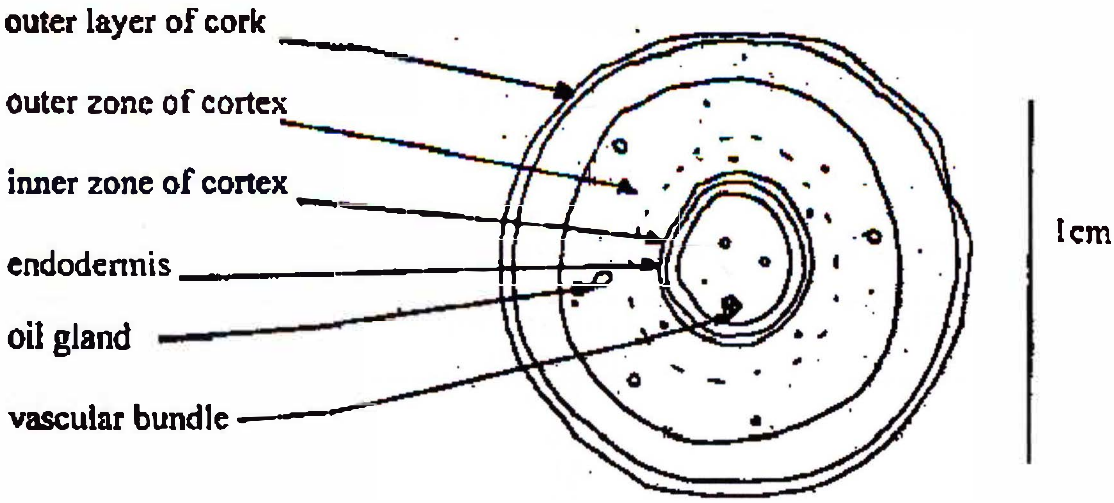


Figure 2.2: Transversal section of ginger rhizome (Wiart and Kumar, 2000).

2.3. The Main Constituents of Ginger

The fresh rhizome contains 1 to 3% essential oil consist mostly sesquiterpenes, e.g., (−)-zingiberene (up to 70%), (+)-ar-curcumene β-sesquiphellandrene, bisabolene and farnesene. Monoterpenoids that occur in traces are β-phelladrene, cineol, and citral. The dried rhizome of ginger contains approximately 1 to 4% volatile oils. These are the medically active constituents of ginger and are also responsible for ginger's characteristic odor and taste. The aromatic constituents include zingiberene and bisabolene, while the pungent constituents are known as gingerol and shogaol (Tyler, 1994). Ginger, which is used in traditional medicine, has been found to possess antioxidant effect that can control the generation of free radicals, where the level has been reported to be high in cancer cells (Norliza *et. al.*, 2006). Antioxidant in the rhizome is carried by the gingerol constituents (Huda-Faujan *et. al.,* 2007). The pungent gingerols degrade to the milder shogaols during storage; high gingerol content and good pungency thus indicate freshness and quality. The table below shows the nutritional composition of ginger, *Zingiber officinale* Rosc.

Table 2.3: The nutritional composition of ginger rhizome, *Zingiber officinale* Rosc.

Composition	**USDA Handbook 8-2[a] (Ground)**	**ASTA[b]**
Water (g)	9.38	7
Food energy (kcal)	347	38
Protein (g)	9.12	8.5
Fat (g)	5.95	6.4
Carbohydrate (g)	70.79	72.4
Ash (g)	4.77	5.7
Calcium (g)	0.116	0.1
Phosphorus (mg)	148	150
Sodium (mg)	32	30
Potassium (mg)	1342	1400
Iron (mg)	11.52	11.3
Thiamine (mg)	0.046	0.050
Riboflavin (mg)	0.185	0.130
Niacin (mg)	5.155	1.9
Ascorbic acid (mg)	-	ND
Vitamin A activity (RE)	15	15

[a]Composition of Foods: Spices and Herbs, USDA Agricultural Handbook 8-2, January 1977.
[b]The Nutritional Composition of Spices, ASTA Research Committee, February 1977.
ND, not detected
Source: USDA (1977)

2.4. The Properties and Uses of Ginger

Fresh and dry ginger is similar in their properties. The only difference is that fresh ginger is not easily digested as the dried type. (Aiyer and Kolammal, 1966). Ginger rhizome has pungent taste and is considered to be converted to sweet products after metabolic changes. Being hot and light, ginger is easily digestible. It has an unctuous quality. Ginger acts as appetizer, curminative, and stomachic. Ginger is acrid, anodyne, anti-rheumatic, anti-phlegmatic, diuretic, aphrodisiac, and cordial. It has anti-inflammatory or anti-oedematous action. It cleanses the throat, is good for the voice (corrective of larynx affections), subsides vomiting, relives flatulence and constipation, and relieves neck pain. Due to its hot property, ginger is capable of causing dryness and thus anti-diarrhoeal in effect. The dry ginger had anti-arthritic and anti-filarial effects. It is also good in asthma, bronchitis, piles, eructation and ascitis. The outer skin of ginger is used as carminative and is said to be a remedy for opacity of cornea. In acute ascitis with dropsy arising from liver cirrhosis, complete subsidence by the use of fresh ginger juice is reported. The juice also acts as strong diuretic (Ahmed and Sharma, 1979)

Food technologist had analysed the use of spices in various preparations and developed a frequency patterning analysis to each spice. This analysis gives information on natural trends and the suitability of the spice for a particular type of preparation. Lawrence and Reynolds (1984) had summarized the information on ginger as follows:

1. Ginger is more suitable for dishes in Japan and China, Southeast Asia, India, and the United Kingdom, and is less suitable or seldom used in the cuisines of other nations; however, it is most suited for Chinese dishes.
2. Ginger is suitable for meat, seafood, milk, eggs, grains, vegetables, fruit, bean seeds and beverages.
3. Ginger is suitable for boiled, baked, fried, deep fried, steamed, food dressed with sauce, pickled, and fresh food; however, more suitable for fried and steamed dishes.
4. Ginger is used for imparting pungency to food in Japan, China, Southeast Asia, India and the United Kingdom; most commonly used in Chinese cooking.

2.5. Commercial Harvesting of Ginger

Ginger can be planted all year around, but the best planting period is in March and the normal period is between January and May (Jesper *et. al.*, 2003). The rhizome of the ginger plant is referred to as a root and is use as a spice in cooking and as a pickled vegetable. The knobby, fibrous mature root has a light yellowish brown skin when fresh. (Paull *et. al.*, 1988). The rhizome is also harvested at a very early stage before fiber development has taken place, for use in pickles and confectionery. Ginger can be harvested earlier. Some harvesting is done about four to five month after cultivation to get "young fresh ginger". It is harvested before the rhizome develops high fiber content (Nishina *et. al.*, 1914). Young ginger dehydrates easily and should be protected from direct sun exposure (Nishina *et. al.*, 1914). Ginger is also harvested less than one year or about seven to eight months after cultivation, when the leaves died. During reaching this age, the rhizome had reached its maturity to be called as "old ginger".

Paull *et. al.* (1988) had stated that desired quality characteristics are includes skin colour, plumpness of tuber pieces, sheen on skin and absence of vegetative sprouts, blemishes, soil and insect injury. Young ginger is bright yellow to brown and has a high sheen with greenish-yellow vegetative buds, but no sprouts (Robert and Ching, 2008). Mature ginger rhizomes are harvested when the plant tops begin to wilt and die. These rhizomes should be plump and with a dry bright yellow-brown skin colour (Paull *et. al.*, 1988). The sheen is soon lost and the skin darkens. The ginger rhizomes are sold in full telescoping 13.6 kg (30 lb) or 6.8 kg (20 lb) fiberboard cartons or 1.7 kg (5 lb) cartons with film bags. Forced-air or room-cooling to 12 to 14°C (54 to 57°F) should be used for pre-cooling.

Delaying harvesting after maturity is reached will reduce the rhizome quality, decrease the storage life and increase the incidence of sprouting during storage (Medlicott, 2003). Medlicott (2003) preferred to a ten second dip treatment in 100 ppm sodium hypochlorite, which will assist in minimizing microbial damage and may improve presentation and requiring rapid drying, preferably in field crates in a well ventilated area. For retail outlet display, the fresh young ginger is considerate to be display with misting, and mature ginger at ambient temperature with no misting.

2.6. Storage Temperature

Commercially, for long term storage of ginger, it is recommended to treat with a fungicide in addition to sodium hypochlorite. Thiobendazole 0.05% for 30 seconds may assist in reducing spoilage incidence and should be given after washing and prior to drying (Medlicott, 2003). Hardenburg (2005) preferred to store ginger in 13 to 15°C (55 to 60°F) with 85-90% relative humidity. Even so, Medlicott (2003) stated that storage of ginger may be carried out at 12°C, 65 to 75% relative humidity, with the rhizomes remaining in a marketable condition for two to three months depending on the initial quality. Mature ginger rhizomes can be stored at 12 to 14°C (54 to 57°F) with 85 to 90% RH for 60 to 90 days. Storage at 13°C (55°F) with 65% RH leads to extensive dehydration and a wilted appearance (Akamine, 1962). Superficial mould growth can occur if condensation occurs on rhizomes. Mature ginger is chilling sensitive if held below 12°C (54°F). Symptoms include loss of skin colour and pitting of the skin, in severe cases there is internal breakdown (Akamine, 1962)

2.7. Relative Humidity

The relative humidity of an air-water mixture is defined as concentration of water vapour in the air. It is expressed as the ratio of the partial pressure of water vapour in the mixture to the saturated vapour pressure of water at a prescribed temperature, where vapour pressure is defined as the pressure exerted by a vapor in equilibrium with the solid or liquid phase of the same substance (Nurul, 2005). Here, the higher the temperature, the higher the saturated vapour pressure. Relative humidity is normally expressed as a percentage and is defined in the following manner: (Perry and Green, 2007)

$$RH = \frac{p_{(H_2O)}}{p^*_{(H_2O)}} \times 100\%$$

Where:

RH is the relative humidity of the mixture being considered;

$p_{(H_2O)}$ is the partial pressure of water vapor in the mixture; and

$p^*_{(H_2O)}$ is the saturated vapor pressure of water at the temperature of the mixture

Relative humidity is measured using a device called hygrometer. It consists of two thermometers, one of which includes a dry bulb and the other of which includes a bulb that is kept wet to measure wet-bulb temperature. Relative humidity can be created in a place to a certain condition using saturated salt solution. To achieve desired humidity, a chemically pure salt (i.e. magnesium nitrate, potassium chloride etc.) is mixed with distilled water to produce slushy mixture. This saturated salt solution will gave certain relative humidity based on the temperature of the storage.

2.8. Physiological Disorder in Ginger

As living tissue, ginger are respires thus releasing carbon dioxide and heat. The respiration rate of ginger is about 5.5 to 6.8 mg CO_2 kg^{-1} h^{-1} (3.1 to 3.8 µL kg^{-1} h^{-1}) at 22°C (72°F). in order to get mL kg^{-1} h^{-1} value, we can divide the mg kg^{-1} h^{-1} rate by 2.0 at 0°C (3°F), 1.9 at 10°C (50°F), and 1.8 at 20°C (68°F); where the calculate heat production is by multiply mg kg^{-1} h^{-1} by 220 to get BTU per ton per day or by 61 to get kcal per metric ton per day.

There are some physiological disorders that occur in ginger. The main observed disorder is dehydration and it is the most common problem that occurs during ginger storage. The rhizomes will lose their sheen and darken rapidly during handling (Akamine, 1962). The symptom of shriveling of the pieces becomes pronounced after the loss of about 10% of harvest weight (Paull *et. al.*, 1988).

In post harvest pathology of ginger, the Fusarium rot disease by *Fusarium* spp. can cause serious problems. The symptoms include pale brown discoloration of the vascular strands (Trujillo, 1963) that invades the rest of the rhizome that becomes brown and dry (Teakle, 1965). The Pythium rot disease by *Pythium* spp. has also been reported, where the ginger rhizome become soft and watery (Haware and Joshi, 1974). Fungicides are not permitted in ginger plantation but reasonable control is obtained if the rhizome are adequately cured and held at 12 to 14°C (54 to 57°F). The saprophytes, such as *Penicillium* spp., may grow on cut ends and injured areas, and although not parasitic, they give the cut ends and surface an unsightly appearance or cosmetic disorder.

CHAPTER 3

MATERIALS AND METHODS

3.1. Materials

3.1.1. Plant Materials and Preparations

The ginger rhizome was used in this study. The rhizomes obtained were fresh from the selected farm. The age of ginger that has been used was six to seven months old, which was its optimum harvesting age for commercial domestic market. A total of about 20.5 kg ± 100 grams of ginger rhizomes has been taken for the study and transported to the laboratory in corrugated and holed box from a single farmer to maintain the quality of the rhizome taken. The plant materials were cleaned from debris and soil residue. Pre-cooling was done by immersing rhizome in cool water. After pre-cooling, plant materials were blotted using tissue paper and air dried and subjected to different treatments and parameter measurements. The initial weight of each replicate of the rhizome was obtained by weighing using a top pan balance, which the weight for each replicate was 100 grams ± 10 grams. The rhizomes' weights before parameter measurement was conducted are also taken to determine the present weight and to calculate the water content of the rhizome.

3.2. Methods

3.2.1. Storing Plant Materials

Treatments applied to the plant materials in different of temperature (5°C, 15°C, and 25°C). This required closed plastic containers and chillers. In addition, the plant materials were also subjected to different relative humidity (75% and 90%). To obtain 75% and 90% relative humidity, saturated salt solution of sodium chloride and water were used (Greenspan, 1977). Initial volume of distilled water and the solution to be used is 400 ml in the 500 ml beaker. The salt (sodium chloride) was added into the water until there was no more salt can be dissolved or some thin crystals appear below the beaker. The solution was poured into the second container, which surrounds the first container that contains the plant material. The container were closed tightly to control the inside humidity from the outside humidity which may change the stability of humidity. The containers for the control treatment were left opened to ensure surrounding humidity reach the plant material. The relative humidity in each treatment was stated in the table below:

Table 3.2: Relative humidity at each chiller (storage conditions) used

Chillers Temperature	Chillers Relative Humidity	Description
5±1°C	82±2%	Saturated solution of sodium chloride was made, put into container and closed
15±1°C	80±2%	Distilled water was added into container and closed
25±1°C	77±2% (room RH)	No liquid or solution added, but container was left open

Hygrometer was used to check the relative humidity in each treatment. The rhizomes were stored for 28 days. To avoid increasing in relative humidity, each container was ensured free from accumulated water vapour. Analyses and weighing samples were done at one week intervals for a month.

Table 3.3: Different storage conditions applied on ginger rhizomes

Treatments	Storage conditions
T1	H1 (5±1°C; 75±2% relative humidity) H2 (5±1°C; 90±2% relative humidity) H3 (5±1°C; 82±2% relative humidity)
T2	H1 (15±1°C; 75±2% relative humidity) H2 (15±1°C; 90±2% relative humidity) H3 (15±1°C; 80±2% relative humidity)
T3	H1 (25±1°C; 75±2% relative humidity) H2 (25±1°C; 90±2% relative humidity) H3 (25±1°C; 77±2% relative humidity)

3.2.2. Parameter Measurements

The ginger samples were divided into three major groups with nine groups for storage treatment, as shown in Table 3.2. Each group contains three replications. The entire groups of samples were tested for parametric measurement of weight loss, texture analysis, colour changes, pH value, total soluble solid (TSS), and water content, before, during and after treatments every week in one week intervals.

3.2.2.1. Texture Analysis

Texture analysis was conducted using TA.XT*plus* Texture Analyzer. On the unpeeled ginger, four different sites were plotted randomly for the measurement on each replicate. The analysis was done on Week 0, 1, 2, 3 and 4. The testing parameters for texture analysis are as follows:

Test mode	Measure force in compression	
Parameters	Pre Test Speed	1.0 mm/s
	Test Speed	0.5 mm/s
	Post Test Speed	5.0 mm/s
	Distance	10.0 mm
Trigger	Auto (5.0g)	
Probe	P/2N needle stainless	

3.2.2.2. Colour Changes

Minolta Chroma Meter (chromameter or colorimeter) was used to measure the colour changes of the rhizome from each treatment, at each replication. On the unpeeled ginger, four different sites were plotted randomly for the measurement. Then, the ginger was cut into four to five large portions and the colour of sleek side was taken. The CIE L* a* b* colour space that provides by chromameter reveals the colour space that owned by ginger. The obtained L* a* b* values were recorded and used to calculate the lightness (L*) and total colour changes of the rhizome colour, at each replicate and treatments. The lightness (L*) value were directly taken from the apparatus result. The colour changes test was carried out for five times on every week of study period. The total colour changes of the ginger samples were calculated using following equation:

$$\Delta C = \sqrt{(L_n - L_o)^2 + (a_n - a_o)^2 + (b_n - b_o)^2}$$

3.2.2.3. pH Value and Total Soluble Solid (TSS)

All portions of the rhizome were mashed to get its raw extract using laboratory blender. The extracts were used to test the pH value using Metler Toledo portable pH meter and total soluble solid (TSS) using Atago handheld refractometer. The TSS content that was measured is °Brix value. The laboratory blender and muslin cloth were also being used in this part. These tests were carried out for five times along the 28 days of experiment period.

3.2.2.4. Water Content

Instead of water, ginger also contains essential and volatile oils. The percentages of these contents were done by using the shredded ginger, put it into moisture dish onto metal tray and bake the ginger in microprocessor oven at 105°C overnight. After overnight, the baked ginger that stays on the lower layer were shifted to the surface and baked overnight again. Then, the baked ginger was weighed using top pan balance for every one hour intervals in five hours, which overall process was about 48 hours. The constant weights that obtained were used to calculate the percentage of water content. The calculation equation was as follows:

$$\text{Water content (\%)} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight}} \times 100$$

3.2.2.5. Percentage of Weight Loss

At each treatment, about 100 grams ± 50 grams of rhizome was reserved for the weight loss percentage calculations. The weight of the ginger was weighed on Week 0, 1, 2, 3 and 4 using top pan balance. The percentage of weight loss was calculated using the following equation:

$$\text{Weight Loss (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

3.2.3. Statistical Analysis

The data collected from all the analyses were analyzed using the analyses of variance (ANOVA). The significant differences ($P<0.05$) between the treatments were determined using Tukey Test. The statistical programme used was the SPSS version 16.

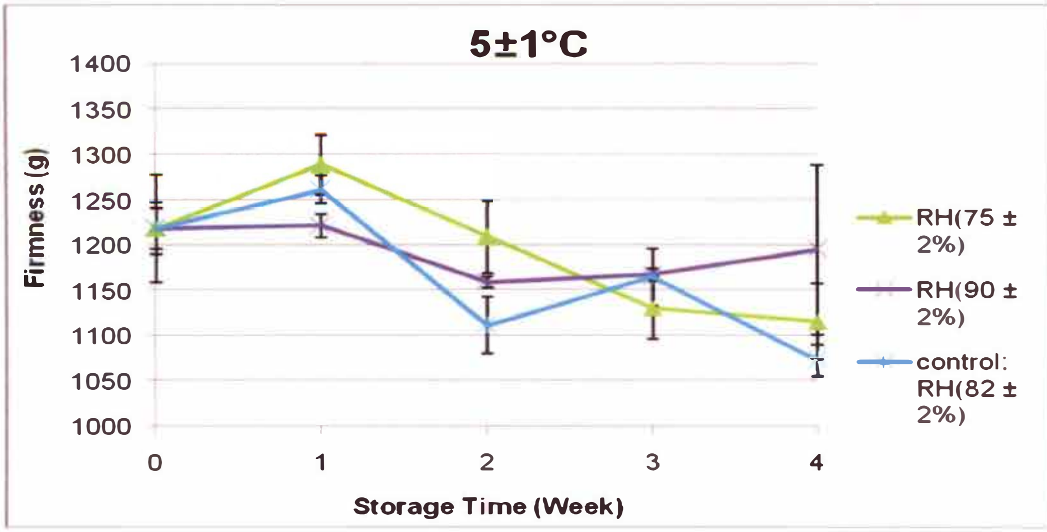
CHAPTER 4

RESULTS AND DISCUSSIONS

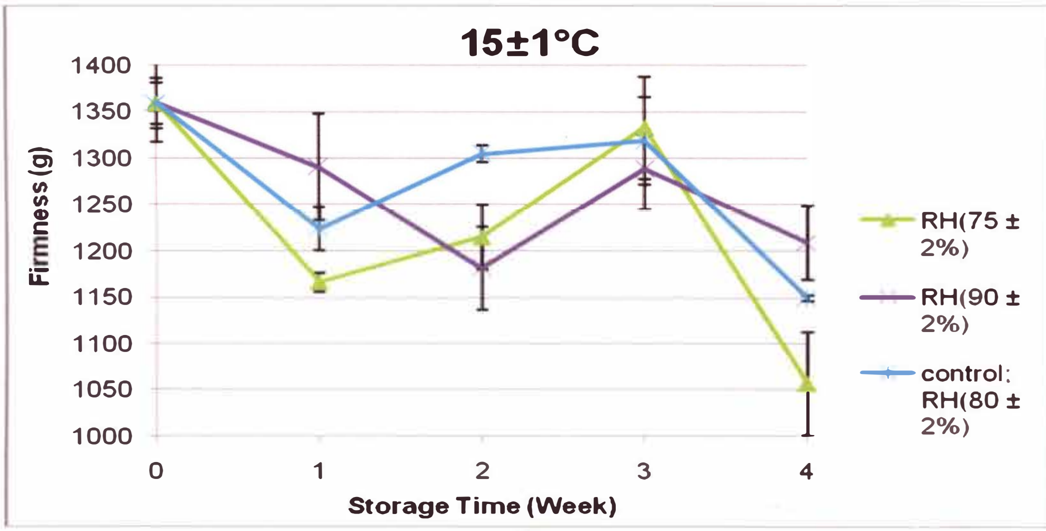
4.1. The firmness of gingers

Ginger is quite famous with the firm texture but quite brittle and easily to snap into fingers or when improper stacking during handling. The firmness of ginger in this study was obtained using TA.XT*plus* Texture Analyser with P/2N probe. Either hard or tender the texture of the products, it will indicate the metabolism and water loss of the products during storage.

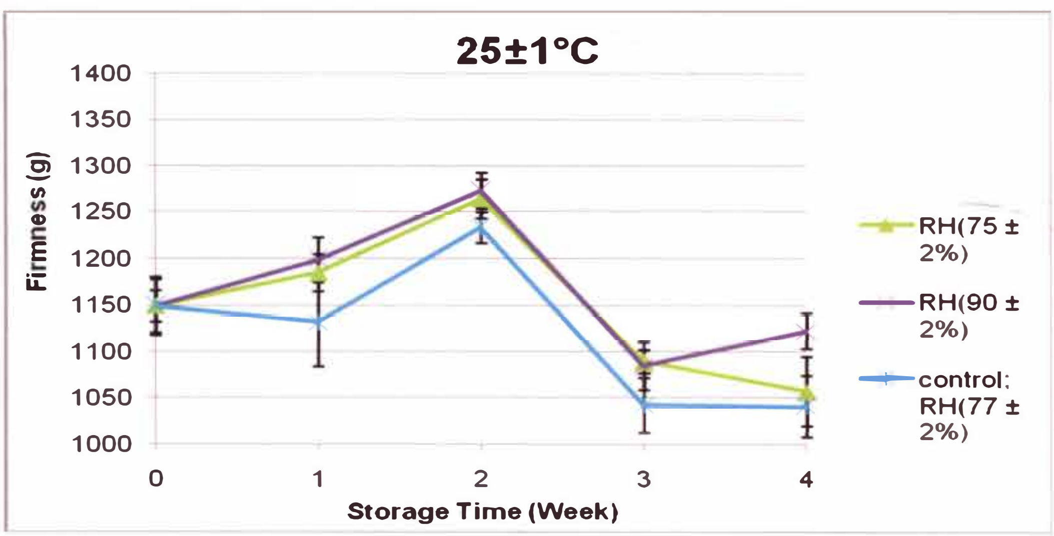
The Figure 4.1 (A) shows the firmness of the ginger stored at temperature 5±1°C with different humidities. All treatments showed inconsistent trends. At all relative humidity treatments, the trends were inclining on the first week and declining on the second week continuously except at 5±1°C; 90±2% treatment. The trend was inclining back on the third and fourth week. The 5±1°C; 75±2% and 5±1°C; 90±2% treatments had given a large differences in firmness due to the vapour pressure deficit between the rhizome and the storage condition. At the end of experiment, ginger that stored at 5±1°C; 90±2% treatment gave a firmness value which almost similar to its initial firmness during Week 0. Since the high humidity contains high water vapour and ginger have high water content in its rhizome, the turgidity of the rhizome was not very affected by the humidity in storage container, thus giving the good condition to store ginger without loosing its turgidity.



(A)



(B)



(C)

Figure 4.1: The firmness of ginger stored at (A) 5±1°C; (B) 15±1°C; (C) 25±1°C at different relative humidity.

Different trend was obtained at relative humidity 82±2% treatment stored at 5±1°C, where the trend was inclining back on the third after inclining on the first week and declining on the second week, and declined at fourth to the lowest firmness value compared to another two treatment's result at the same time. Such inconsistent trend lines shows that the rhizome was very affected by storage humidity and temperature, thus affecting its turgidity and firmness to the lowest quality. It was also caused by the method of sampling, where the rhizome might be differing from the maturity aspect; even the rhizomes were come from the same fingers during harvesting.

From the data obtained, the Figure 4.1 (B) shows the firmness of the ginger stored at 15±1°C temperature with different humidities. All treatments applied showed quite consistent trends. At relative humidity 75±2%, the trend was declining on first week. Increasing in firmness was shown on Week 2 and Week 3 but then declining to the lowest value from all firmness values in graph at Week 4. At relative humidity 90±2% treatment trend in the graph, the trend was declining on first week. The firmness was increasing as shown on second week and slightly in the third week. The huge declining in value was occurring in this treatment at the fourth week. A large slope on both treatments trends may cause by the rhizome loosing its turgidity due to higher temperature and inconsistency at humidity in the storage container.

Large differences between both treatments' firmness had shown the suitability of storage condition in order to sustain the firmness of ginger. At relative humidity 80±2%, the trend was declining on first and second week but increasing on the third week before declined back again in a large value on Week 4, which marked in the middle of the end firmness value of another two treatments. In this temperature and humidity, the vapour pressure in the rhizome was struggling to maintain its water content and being nearly equal to the humidity in the storage container thus results in low firmness compared to the sample's initial firmness. This treatment, however, give better choices in storing ginger due to the firmness and turgidity results was higher than the relative humidity 75±2% treatment.

The Figure 4.1 (C) shows the firmness of the ginger stored at respective temperature and humidity. All treatments applied showed quite consistent trends. At all treatments, the trend was inclining on first and second week before drop at third and fourth week. At relative humidity 90±2%, there was a inclining in firmness value on Week 4. In 25°C, there were no big differences between both treatments in order to maintain the firmness of ginger except at the end of the treatment's assessment. This means that, the higher temperature can cause the faster water to become vapour and saturated vapour will not really affecting the water content in the samples, thus results the firmness of ginger. At relative humidity 77±2%, this treatment results a solemn trend line that lower than another two treatments. Warmer temperature with open air condition which was dryer than other treatments can largely affect the vapour pressure deficit in the sample. Ginger tends to loose more water content, thus effects on its turgidity and firmness.

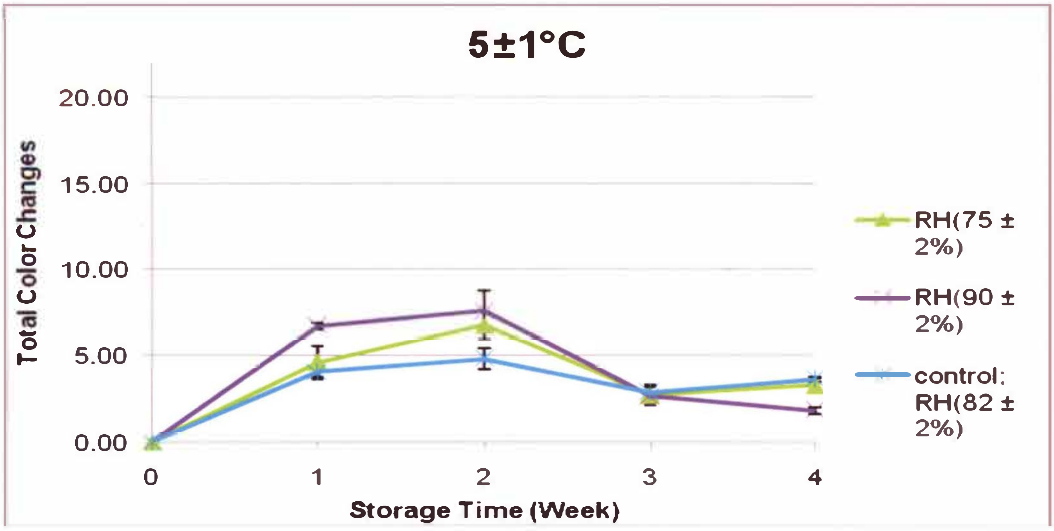
Statistical analysis with Tukey test on the firmness of ginger was done after the analysis was completed (Appendix A). From the statistical evaluation by the storage time, there was no significant difference between all treatments done. There was also the same result when the statistical evaluation by the temperature and humidity treatments; no significant difference between the treatments effect on the firmness of ginger. Based on the analysis, the ginger rhizome's firmness was not affected by all treatments, thus there were no differences on where the rhizome were stored, respectively.

4.2. Total colour changes of ginger skin

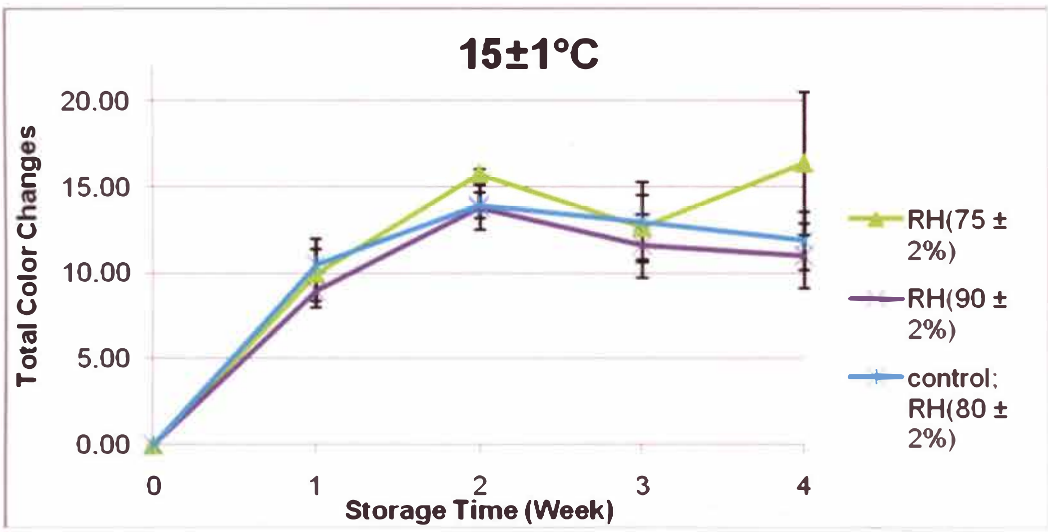
The colour changes on the ginger skin were taken using Minolta Chroma Meter. The parameter taken were L* value for lightness, a* value for red-green colour space and b* for yellow-blue colour space. From the achieved L*, a* and b* value, the total colour changes (ΔC) was calculated. Colour of the ginger rhizome usually indicates the maturity stages during post harvest maturity selection.

Figure 4.2 (A) shows the total colour changes on the skin of the ginger stored at 5±1°C temperature and different humidity. All treatments showed consistent and similar trends. At 5±1°C; 75±2% treatment, the trend was inclining on the first week and second week. There was some declining at Week 3 before a slightly incline on Week 4. At relative humidity 90±2%, the trend was inclining on the first week and second week but declining on the third and fourth week. Between both treatments, the relative humidity 90±2% treatment gave the greater changes in colour compared to the relative humidity 75±2% treatment. The high moisture content in the rhizome does not affect the colour pigment lightness during early storage. At the end, the total colour changes in this treatment were become lower due to pigment degradation.

Even so, the total colour changes at the relative humidity 75±2% treatment at the end of the storage time were a bit higher. This was probably caused by the differences and variability in sampling method, where the maturity of the ginger was not at the same maturity at each parameter assessed. At 5±1°C; 82±2% treatment, the trend has shown the same trend as two treatments but with slightly inclined back at fourth week. This treatment also does not give a large differences in total colour changes and the rhizome might be came from the same finger as the relative humidity 75±2% treatment's sample which shows in the graph obtained.



(A)



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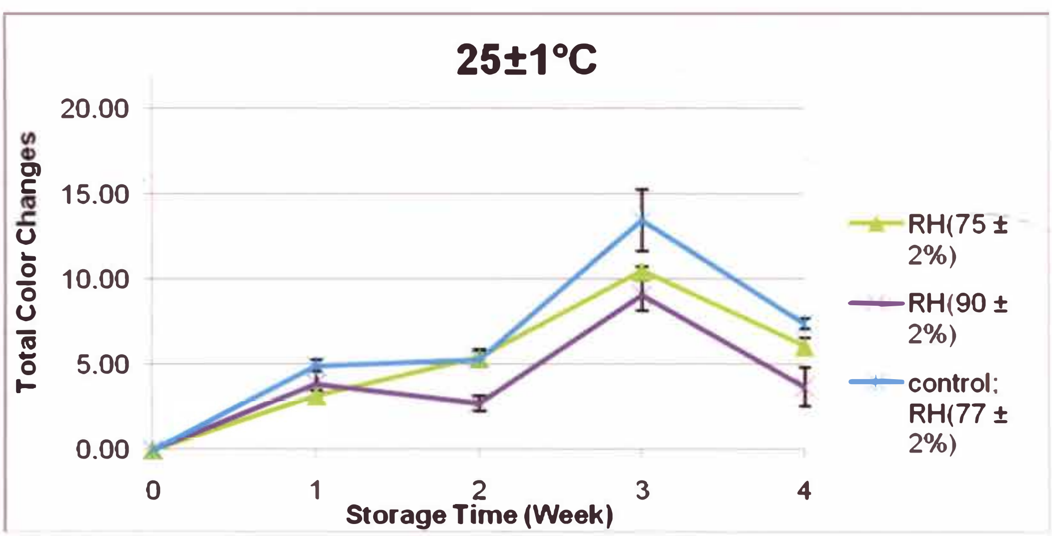


(C)

Figure 4.2: The total colour changes of ginger skin stored at (A) 5±1°C; (B) 15±1°C; (C) 25±1°C at different relative humidity.

The entire trend lines were nearly crossed each other which means that even ginger was stored in various humidity, as its still in 5±1°C, there was no differences in the ginger rhizome's skin colour changes.

Figure 4.2 (B) shows the total colour changes on the skin of the ginger stored at 15±1°C temperature and different humidity. At all treatment, the consistent trends were obtained, as there was inclining values on the first week and second week before declining at third week and fourth week. At relative humidity 75±2%, the trend was inclining on the first week and second week, declining on the third and inclining fourth week. There was actually no difference between both treatment, between 15±1°C; 75±2% and 15±1°C; 90±2% treatments, even the relative humidity 75±2% treatment had given a slope at Week 4 of the experiment, it may caused by the different maturity of sample between assessment on Week 3 and Week 4. The similar trend line was obtained at relative humidity 15±1°C; 80±2% treatment, where the trend was inclining on the first week and second week but declining on the third and slightly inclined back at fourth week. The declining in total colour changes value in all treatments may cause by the degradation of the colour pigment of the ginger skin, due to storage time.

The Figure 4.2 (C) shows the total colour changes on the skin of the ginger stored at respective temperature and humidity. At all treatment, the consistent trends were obtained, inclining on the first week, declining at second week, rapid inclining on the third but declining back at fourth week. At 25±1°C; 75±2% treatment, the ginger that stored at this treatment only had a slight slope on Week 2 and the total colour changes value was declined on fourth week. This treatment also results in a higher total colour changes value at the end of experiment compared to the relative humidity 90±2% treatment which had visible slope on the same time and lower in total colour changes value. Here, the high differences in humidity between storage container and sample had given the sample better colour appearances due to water loss and saturated colour pigment.

The similar trend line was obtained at relative humidity 77±2% treatment, where the trend was inclining to the highest peak on the third and declined back at fourth week. At the end of experiment, the total colour changes of the ginger that stored in 25±1°C; 77±2% treatment was higher than the ginger that stored at the relative humidity 75±2% and 90±2% treatment. As stated before, the water loss of ginger in this treatment were also induced by open air movement had caused the colour pigment of the ginger skin become more saturated and the rapid declining value was caused by degradation of the rhizome due to budding and senescence.

The statistical analysis with Tukey test on the L*, a* and b* values of gingers skin was done after the analysis was finished (Appendix B, C and D). From the statistical evaluation by the storage time on L* and a* values, there was no significant difference between all treatments done. Even so, on b* values, there were significant between all treatments done. At 5±1°C; 75±2% and 90±2% treatments, the b* values that obtained on Week 1 was significantly higher than the values that obtained on Week 3, 4, 2 and 0, in descending order. This indicates that between both treatments, there were no significant on treatments done. At 5±1°C; 82±2% treatment, the b* value that obtained on Week 3 was significantly higher than the values that obtained on Week 1, 4, 2 and 0, in descending order.

At 15±1°C; 75±2% treatment, the b* value on Week 3 was significantly higher than the value obtained on Week 1, and followed by Week 2, 0 and 4. At 15±1°C; 90±2% treatment, the b* value on Week 3 was significantly higher than the value obtained on Week 4, and followed by Week 2, 0 and 1. This indicates that between both treatments, there were significant differences on the treatments done. At 15±1°C; 80±2% treatment, the b* value that was obtained were same as resulted at 15±1°C; 90±2% treatment, which shows that between these treatments there were no significant difference.

At 25±1°C; 75±2% treatment, the b* value on Week 4 was significantly higher than the value obtained on Week 1, and followed by Week 0, 2 and 3. At 25±1°C; 90±2% treatment, the b* value on Week 2 was significantly higher than the value obtained on Week 4, and followed by Week 3, 2 and 0. Between these treatments, both treatments had significant differences. At 25±1°C; 77±2% treatment, the results obtained were same as 25±1°C; 90±2% treatment, thus shows that there was no significant difference between both treatments. After the evaluation, the best treatment base on the storage time was 15±1°C; 80±2% treatment.

From the statistical evaluation by the temperature and humidity treatments, there were significant differences between the treatments effect on the L* values. On Week 0, 2 and 4, the 5±1°C; 90±2% treatment had given a higher significant value compared to all treatments while on Week 1 and 3, there were no significant difference between all treatments. There were no significant difference between the treatments effect on a* values after the evaluation done.

From the evaluation of b* value of ginger skin, every treatments had shows significant differences on every week. On Week 0, the b* values from 25±1°C; 75±2%, 77±2% and 90±2% treatments were significantly higher than the values that obtained from 5±1°C; 75±2%, 15±1°C; 90±2% and 75±2% treatments. The 5±1°C; 90±2%, 82±2% and 15±1°C; 80±2% treatments were significantly lower that the treatments mentioned before. On Week 1, the b* values obtained from 25±1°C; 90±2% and 77±2% treatments were significantly higher than the values that obtained from 5±1°C; 75±2%, 25±1°C; 74±2% and 15±1°C; 90±2% treatments. The 5±1°C; 90±2%, 82±2%, 15±1°C; 75±2% and 80±2% treatments were no significant difference each other thus significantly lower that the treatments mentioned before. On Week 2, the b* values obtained from 5±1°C; 75±2%, 15±1°C; 75±2% and 90±2%, 25±1°C; 90±2%, and 77±2% treatments were significantly higher than the values that obtained from 25±1°C; 75±2% treatment.

The other treatments were had no significant difference thus significantly lower than the mentioned treatments before. On Week 3, the b* value that obtained from 15±1°C; 75±2% treatment was significantly higher than the other treatments that were no significant different each other. On Week 4, the 25±1°C; 90±2% and 75±2% treatments had significantly higher than 25±1°C; 75±2% treatment, where the other treatments were had no significant different each other thus significantly lower than the three treatments before.

Based on the analysis, the best treatment was 15±1°C; 80±2% treatment which showed the least b* value changes. The ginger rhizome skin's colour was affected by all treatments especially on the b* values. There were differences on the yellowish colour of the ginger skin on where the rhizomes were stored, respectively.

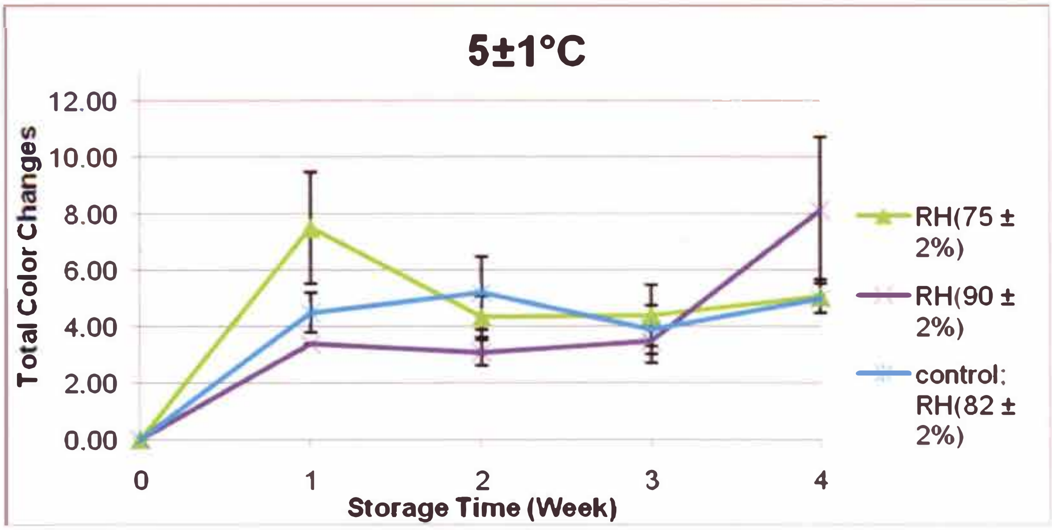
4.3. Total colour changes of ginger flesh

The colour changes on the ginger inner flesh were taken using Minolta Chroma Meter. The parameter taken were L* value for lightness, a* value for red-green colour space and b* for yellow-blue colour space. From the achieved L*, a* and b* value, the total colour changes (ΔC) was calculated. Colour of the ginger rhizome's flesh usually indicates the maturity stages during post harvest maturity selection and as a closer observation to the pungency of ginger variety.

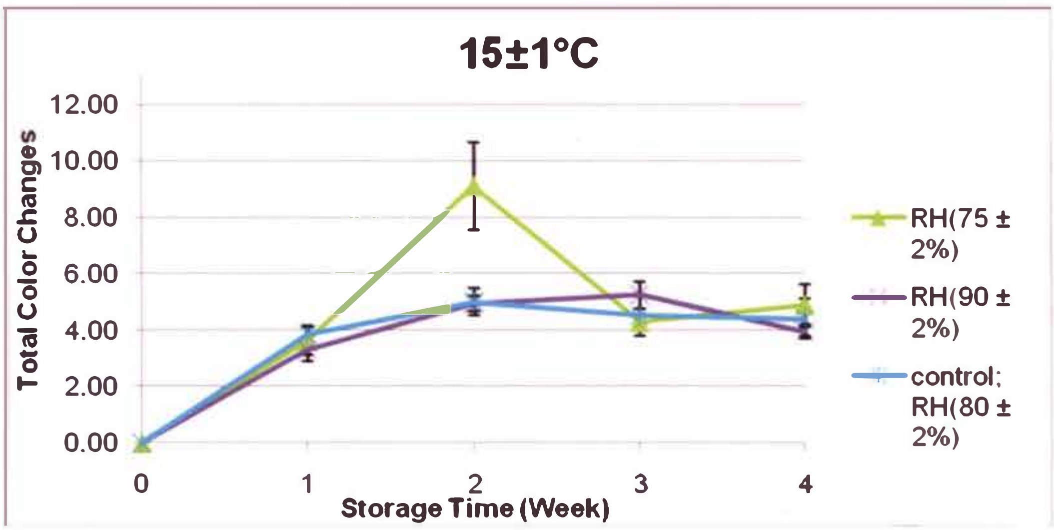
Figure 4.3 (A) shows the total colour changes on the flesh of the ginger stored at 5±1°C temperature with different humidity. All treatments showed inconsistent trends. At the beginning of the experiment, all the total colour changes had shown a high value, which may caused by temperature and humidity shocked as visibly shown at 5±1°C; 75±2% and 5±1°C; 82±2% treatments trend line. At relative humidity 75±2%, the trend was inclining promptly on the first week but declined on second week. There was slight inclining from Week 2 to Week 3 until Week 4.

At relative humidity 90±2%, the trend was differ, with inclining on the first week, slightly declined on second week before slightly inclined back on the third and reaches the highest peak on the fourth week. The inconsistent value on the trend line by the relative humidity 75±2% treatment on Week 1 and the relative humidity 90±2% treatment on Week 4, was suspected caused by the destructive type of sampling, therefore the ginger has been separated into smaller fingers and varies in maturity. Different trend was obtained at relative humidity 82±2% treatment, where the total colour changes of the ginger slice was increased from Week 0 to the second week until drop at third week but inclined back on fourth week.

At the end of the experiment, the total colour changes of the ginger slice in this treatment were reaching equal value as the relative humidity 5±1°C; 75±2% treatment result. These similar values were probably caused by too much moisture loss from the samples due to low storage humidity and high air velocity in the storage condition. From the result, we can see that there were no differences in storage condition at 5±1°C in any humidity treatments available.



(A)



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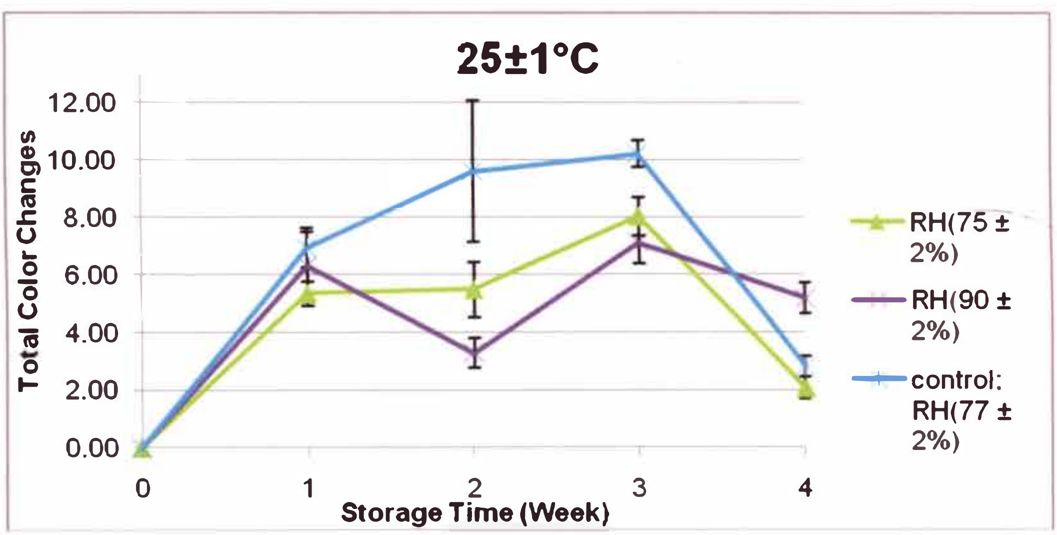


(C)

Figure 4.3: The total colour changes of ginger flesh stored at (A) 5±1°C; (B) 15±1°C; (C) 25±1°C at different relative humidity.

Figure 4.3 (B) shows the total colour changes on the slice of the ginger stored at 15±1°C temperature with different humidity. All treatments showed consistent trends except the trend of the 15±1°C; 75±2% treatment. At this treatment, the trend was inclining rapidly on the second week. There was much declining at third week before a slight incline on fourth week. At relative humidity 90±2%, the trend was inclining on the first week to the third week but declining on the fourth week. This humidity storage had result a curve-like trend which shows a increasing of colour pigment in the sample before it was declined at the end of the experiment.

A totally high value of total colour changes at relative humidity 75±2% treatment at Week 2 assessment was positively caused by the destructive method of sampling where the ginger has been separated into smaller fingers and varies in maturity at each parameter assessed. The similar trend line was obtained at 15±1°C; 80±2% treatment, as in 15±1°C; 90±2% treatment. This control treatment trend line, when compared to another two treatments, shows that there was not much variable in total colour changes of ginger inner flesh between every humidity treatments when stored in 15±1°C treatment of temperature and different humidity storage.

The obtained graph on Figure 4.3 (C) shows the total colour changes on the flesh of the ginger stored at 25±1°C temperature and three different humidities. All treatments showed consistent trends where they goes to a rapid increasing in total colour changes of inner flesh in the early of the experiment and also rapidly decrease at the end. However, at 25±1°C; 90±2%, the trend was declining back at fourth week. Compared between both treatments, 25±1°C; 75±2% and 25±1°C; 90±2%, the ginger stored at 75±2% humidity had resulted lowest total colour changes at the end of the treatment than the ginger stored at 90±2% humidity which resulted to the highest total colour changes at the same evaluation week. This may caused by the high storage humidity which lowing the moisture loss from the sample, thus minimize the degradation of the colour pigment during the storage period. The trend line that obtained at 25±1°C; 77±2% treatment has shown a bit difference, where the trend was inclining on the first week to the highest peak on the third week but declined very much at fourth week as similarly resulted at 75±2% humidity storage. Some differences in the trend lines at all treatments were probably caused by the variability and destructive type in sampling method, where the maturity of the ginger was not at the same maturity at each parameter assessed.

In the other hand, temperature, humidity and air velocity in the storage may contribute to the total colour changes in the ginger's inner flesh where the controlled treatment tends to give similar results as the low humidity treatment. The air was moving around the controlled sample, causing moisture loss as the water vapour deficit occur in the low humidity treatment in order to balance the water content between the sample and its surrounding humidity.

The statistical analysis with Tukey test on the L*, a* and b* value of ginger flesh was done after the analysis was completed (Appendix E, F and G). From the statistical evaluation by the storage time, there were no significant difference between all treatments done on L* and a* values evaluation. After the b* values evaluation, at 5±1°C; 90±2%, 75±2% and 82±2% treatments, 15±1°C; 80±2% treatment, 25±1°C; 75±2% and 90±2% treatments, were significantly higher on Week 0 and 3 than on Week 1, 2 and 4. At 15±1°C; 90±2% and 25±1°C; 77±2% treatments, this treatments were significantly higher on Week 0 compared to other treatments which were had no significant difference. At 15±1°C; 75±2% treatment on Week 3, the value was significantly higher than Week 0, 1, 2 and 4.

The statistical evaluation by the temperature and humidity treatments on the L* values, there was no significant difference between the treatments effect on the L* value of ginger flesh. After conducting a* values evaluation, at 25±1°C; 90±2% treatment, this treatments had significantly higher values than 25±1°C; 75±2% treatment on Week 0. At the same treatment, the a* value on Week 1, 2 and 4 had shown no significant difference each other but significantly lower than the Week 0 storage and significantly higher than Week 3 storage. The evaluation on b* values had shown no significant difference value at storage treatments. Based on the analysis, the ginger rhizome flesh's colour changes was effected by all treatments at a* and b* values where the ginger flesh had changed on more yellow and reddish colour, thus there were differences on where the rhizomes were stored. Here, the treatment at 15±1°C; 90±2% had gave the best treatment to the ginger flesh colour changes which the colour was not developed too much compared to the ginger stored at other treatments, respectively.

4.4. pH

The pH of the ginger was measured and calculated in order to observe the acidity, neutrality and/or alkalinity before, during and after the storage treatment. The pH indicates the existence of organic acid that contained in the ginger that might be linked to the degradation of ginger during storage.

Figure 4.4 (A) shows the pH of the ginger stored at 5±1°C temperature and three different humidities. All treatments showed consistent trends where they were

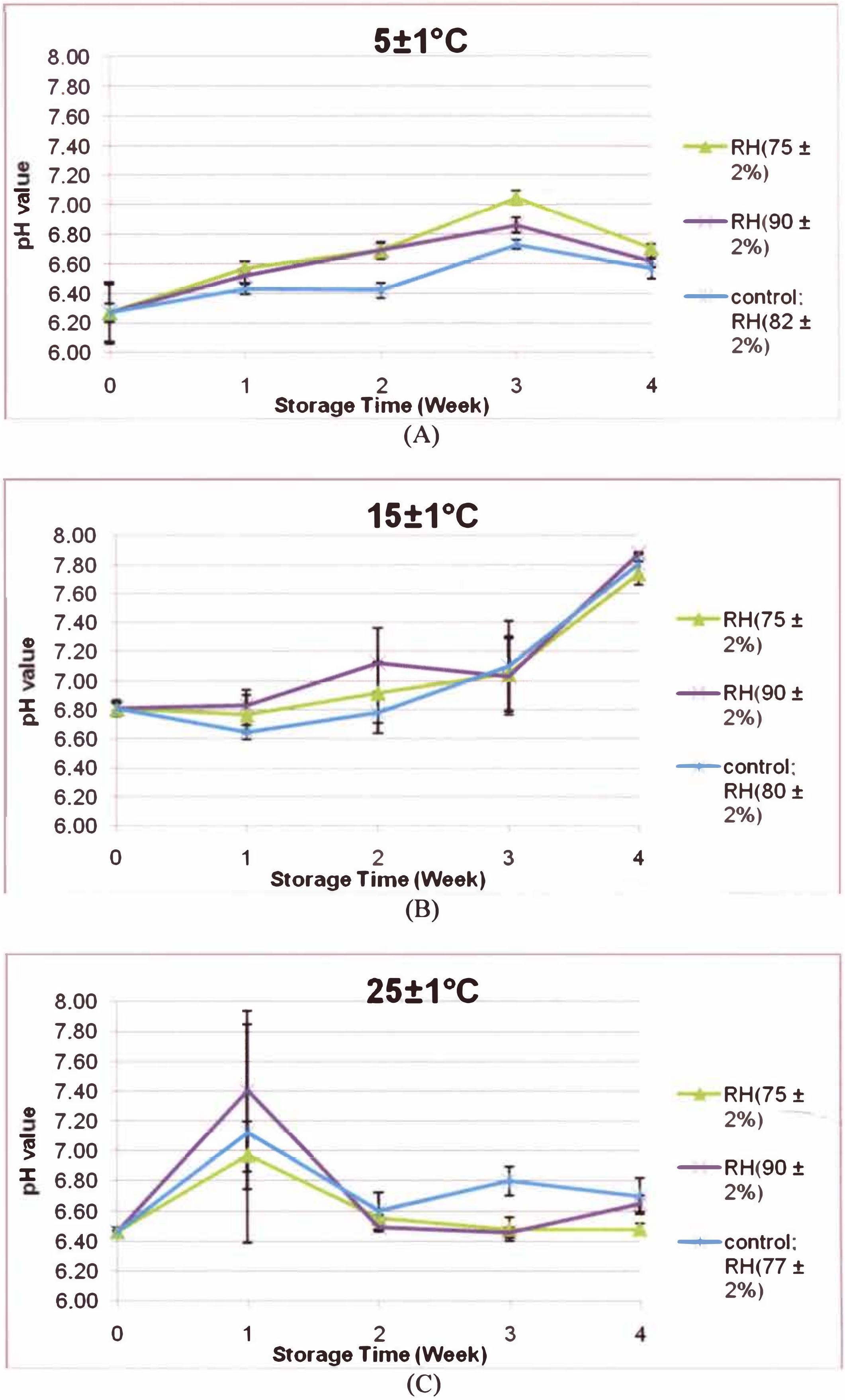


Figure 4.4: The pH of ginger stored at (A) 5±1°C; (B) 15±1°C; (C) 25±1°C at different relative humidity.

inclining on the first week to the third week but declining some on the fourth week. Both treatments, 5±1°C; 75±2% and 5±1°C; 90±2%, shows the same pH value during Week 2 and had the highest pH value on the third week but the 75±2% humidity treatment resulted in neutral pH rather than acidic at the relative humidity 90±2% treatment. Between these two treatments, we can say that there were no visible differences in the pH value when we stored the ginger rhizome in any from both humidities at 5±1°C treatment. The same trend was obtained at 5±1°C; 82±2% treatment, where the pH of the ginger was increased from Week 0 to the first week, slightly drop at second week but inclined back on third week before declined back on week 4. Reaching the highest pH on the third week, this treatment has acidic pH value, and the trend does not give any differences if the ginger was stored in any humidity in the same temperature.

Figure 4.4 (B) shows the pH value of the ginger stored at 15±1°C temperature and three different humidities. All treatments showed consistent trends where they were slightly declining on the first week but inclining on the second week until fourth week. At relative humidity 90±2%, the trend was inclining second week but slightly declining on the third and inclining back on fourth week. There was only a slight differences both treatments 15±1°C; 75±2% and 15±1°C; 90±2% treatments between Week 0 to Week 3 where the ginger that stored in the relative humidity 90±2% treatment had some increases in pH value during Week 2 to some neutral-to-alkaline pH. Otherwise, the pH of the relative humidity 75±2% treatment was neutral and altogether reaches the same point as the 90±2% humidity treatment in 15±1°C. The similar trend line as in relative humidity 75±2% was obtained on relative humidity 80±2% treatment, where the trend was declining on the first week but inclining on the second, third and fourth week continuously. Despite of lower pH during Week 1 and

Week 2, there were no distinctive differences between the pH of the ginger that stored in this treatment compared to the 75±2% and 90±2% humidity treatment.

The obtained graph on Figure 4.4 (C) shows the pH value of the ginger stored at 25±1°C temperature and humidity. All treatments showed consistent trends which had the highest pH during Week 1. At 25±1°C; 75±2% treatment, the trend was declined on second week to fourth week. At 25±1°C; 90±2% treatment, the trend was inclining back at fourth week. Within both treatments, the pH value was only differing during Week 1 while in the other week, there is no distinctive difference. The trend line that obtained at 25±1°C; 77±2% treatment has shown a bit difference, where the trend was inclining on the third week.

Statistical analysis with Tukey test on the pH of ginger was done after the analysis was finished (Appendix H). From the statistical evaluation by the temperature and humidity treatments; there were significantly higher between the treatments effect on the pH value of ginger. Based on the analysis, the ginger rhizome's pH at all treatments were increasing over the storage time on Week 4. The pH values that obtained at 15±1°C treatment had significantly higher than 5±1°C and 25±1°C treatments. From the statistical evaluation by the storage time, there was no significant difference between all treatments done on Week 0. However, started on Week 1 until Week 4, the pH values of each treatment started to show significant differences among each other. On Week 1, 2 and 3, pH value of 5±1°C; 82±2% treatment was significantly higher if compared to the other treatments. This indicates that the treatment had undergone some decreasing in pH value to be more acidic. The inconsistencies of values were due to the destructive method of the ginger sampling. Here, the least pH changes was obtained at 25±1°C; 77±2% treatment.

4.5. Total soluble solid

Total soluble solid is a measurement used to indicate the content of soluble solid in the produces, mostly the content of sugar. This measurement is important to determine the degradation of the ginger composition to senescence or to produce budding over the storage time in different temperature and humidity.

Figure 4.5 (A) shows the total soluble solid content of the ginger stored at 5±1°C temperature and different humidity. All treatments showed consistent trends where there was inclining value on the first week and back to the initial content value on the second week. After the second week, the total soluble solids were increasing but decreasing back after Week 3. At 5±1°C; 75±2% treatment, the trend was inclining from the third week until the fourth week. This increasing in total soluble solid might be caused by the moisture loss from the sample due to vapour pressure between the sample and its surrounding environment. The more water loss, the higher the total soluble solid content in the ginger treated at 5±1°C; 75±2% treatment because of the water content inside the sample had become saturated compared with 5±1°C; 90±2% treatment. At 5±1°C; 90±2% treatment, the total soluble solid content was the lowest because there was smaller water loss in the ginger samples stored at this treatment.

The same trend was obtained at 5±1°C; 82±2% treatment, where the total soluble solid of the ginger was increased from Week 0 to the first week, slightly drop at second week but inclined back on third week before declined back on Week 4. The total soluble solid of the ginger at this treatment was quite higher due to air movement on the sample's surrounding. Even so, there was no bud growths on the ginger stored in the 5±1°C treatment at any humidity tested.

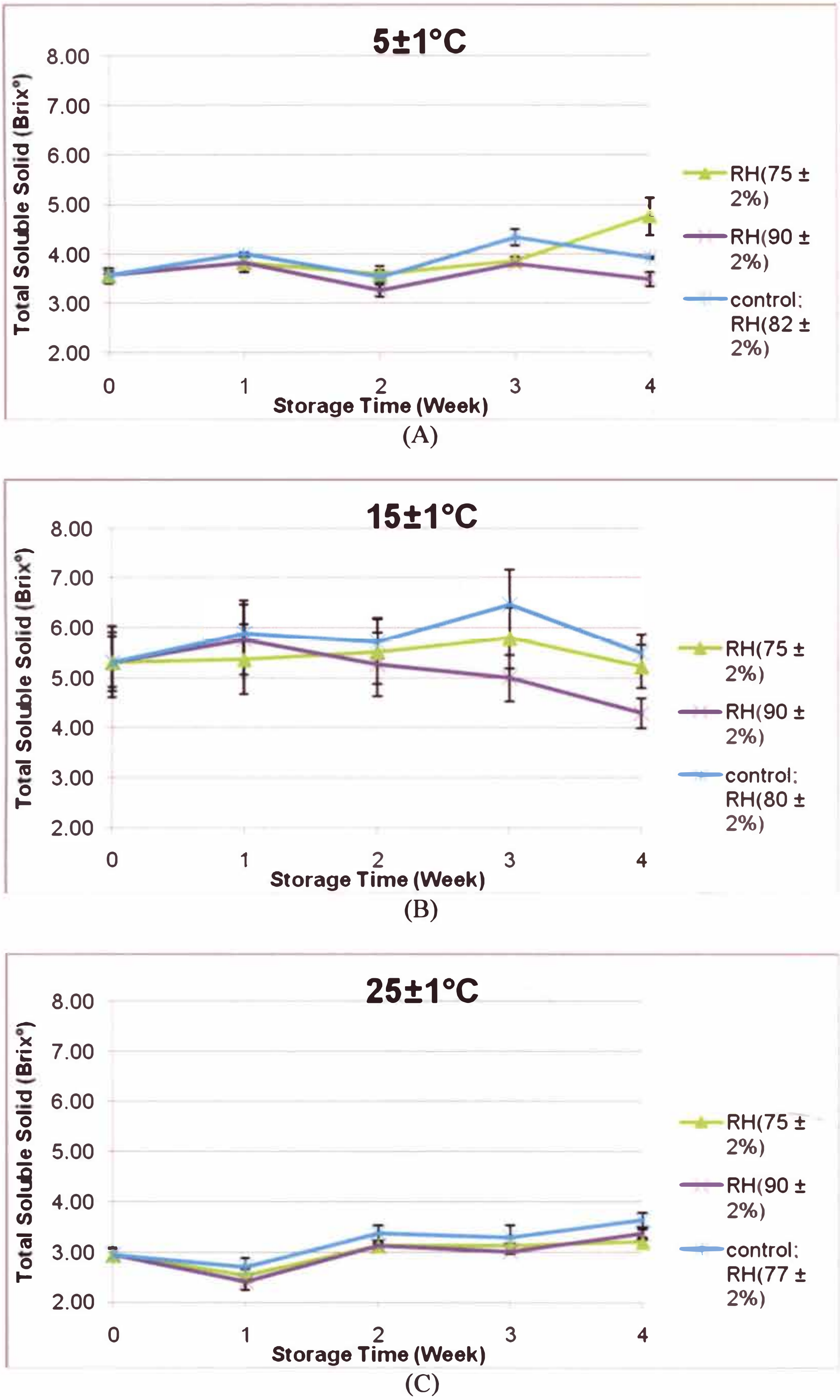


Figure 4.5: The total soluble solid content of ginger stored at (A) 5±1°C; (B) 15±1°C; (C) 25±1°C at different relative humidity

The graph in Figure 4.5 (B) shows the total soluble solid content of the ginger stored at 15±1°C temperature with three different humidities. All trends were consistent where all treatments were inclined at the early of the experiment and declined at the end of the experiment. At 15±1°C; 75±2% treatment, the total soluble solid of the ginger had shown small inclining value from Week 0 to Week 3 but declined on the Week 4. At 15±1°C; 90±2%, the trend was inclining on the first week and back to the initial content value on the second week. After the second week, the total soluble solids were decreasing until the fourth week. Both treatments show a slightly different trend.

The small differences in total soluble solid content of the gingers stored at 15±1°C; 75±2% treatment might be caused by the samples water content that not too much different from the vapour pressure between the storage humidity. In the other hand, the low content of total soluble solid of the gingers stored at 15±1°C; 90±2% treatment was resulted by a high water content in the ginger rhizomes during assessment, which caused by introducing a high moisture condition to the high water content produce.

At 15±1°C; 82±2% treatment, the total soluble solid of the ginger was increased from Week 0 to the first week, slightly drop at second week but inclined back on third week before declined back on Week 4. The total soluble solid content of the ginger was assumed higher at the end of experiment at this treatment but the declining in value assessed was probably caused by degradation of the organic acid in the rhizome to produce bud, since there were many new buds found on the sample. Furthermore, the declination may also caused by the method of sampling, where the rhizome might be differ from the maturity aspect; even the rhizome were come from the same fingers during harvesting.

The obtained graph on Figure 4.5 (C) shows the total soluble solid of the ginger stored at 25±1°C temperature with three different humidities. All treatments showed consistent and same trends on each other. At 25±1°C; 75±2%, 25±1°C; 90±2% and 25±1°C; 77±2% treatments, all of the trend lines has shown the same lines, with a bit difference on the 25±1°C; 75±2% treatment. Here, the trend was inclining on the first week and declining on the second week. The following week was inclined in trend but declined slightly at fourth week. Compared to all treatments, there were no distinctive differences between the total soluble solid of the ginger that stored in 25±1°C temperature treatment.

The value of total soluble solid (TSS) was determined by the conversion or degradation of organic acid and starch to sugar in certain biochemical changes in the cell during storage. Statistical analysis with Tukey test on the TSS of ginger was done after the analysis was completed (Appendix I). From the statistical evaluation by the temperature and humidity treatments; there was no significantly difference between all the treatments effect on the TSS of ginger.

On the statistical evaluation by the storage time, there was also no significant difference between all treatments done on Week 1 if compared to the other weeks. However, on Week 0, 2, 3 and 4, the TSS of each treatment started to show differences among each other. At 25±1°C; 90±2% treatment, the TSS value was significantly higher if compared to the other treatments on the mentioned week above. This indicating that the treatment had undergone some increasing in TSS values, where the metabolic activities in the rhizomes increase due to higher temperature and humidity. This had caused the organic acids and starch in the rhizomes converted to the sugar to produce new buds. The least TSS changes was at 5±1°C; 90±2% which gave better storage retention for the ginger rhizome, respectively.

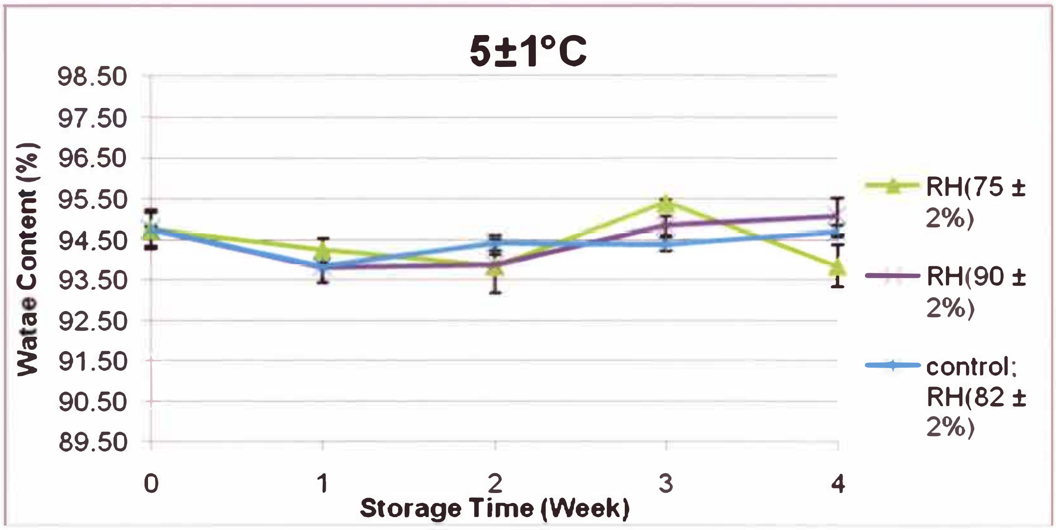
4.6. Water content

The water content assessment was done to determine the water content range in the ginger rhizome after stored in certain temperatures and humidity. The ginger rhizome were heated in the oven at 105°C, for 48 hours to ensure all the water content had been dried out.

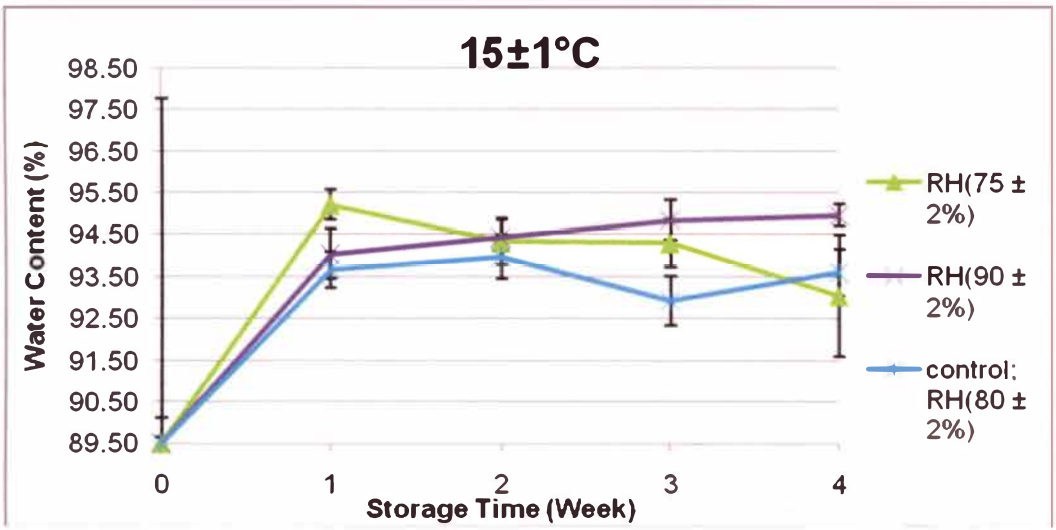
Figure 4.6 (A) shows the water content percentages of the ginger stored at 5±1°C temperature with three different humidities. All treatments showed consistent trends where most of the water contents declining on Week 1 and Week 2. At 5±1°C; 75±2% treatment, the trend was declining on the first week until the second week. After the second week, the water content percentage was increasing until the third week but the declined during Week 4. At 5±1°C; 90±2% treatment was declined on first week but then raising until fourth week. Compared on both treatments, the ginger that stored in 5±1°C; 75±2% treatment tends to loose more water content because of different vapour pressure between the sample and storage condition.

The high water content during Week 3 might be caused by the destructive method of sampling, where the rhizome might be differ from the maturity aspect and water content; even the rhizome were come from the same fingers during harvesting. The ginger that stored at 5±1°C; 90±2% treatment had increased in water content percentage during third and fourth week which resulted by introducing a high moisture condition to the high water content produce.

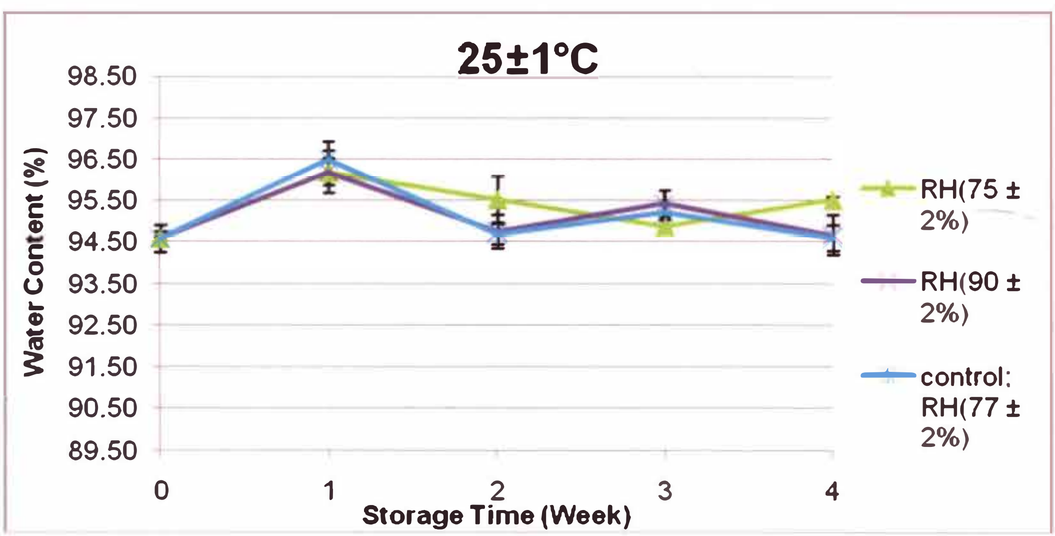
The same trend was obtained on 5±1°C; 82±2% treatment, where the differences in percentage were not varies too much instead of Week 2. This was because even the ginger stored in low temperature and moderately high humidity, the air movement around the samples were not a dry air, so the water content inside the



(A)



(B)



(C)

Figure 4.6: The water content percentage of ginger stored at (A) 5±1°C; (B) 15±1°C; (C) 25±1°C at different relative humidity

sample was not pulled out too much until it could affect the whole produce stored in the storage condition.

Figure 4.6 (B) shows the water content percentage of the ginger stored at 15±1°C temperature and humidity. All treatments showed consistent trends at the early of the experiment with rapid increasing water content percentage. At 15±1°C; 75±2% treatment, the trend was starts to decline at second week. There was a slight inclining at third week before the value was decline back on fourth week. At 15±1°C; 90±2% treatment, the trend was inclining on the first week and continuously to the second week until the end of the experiment. Compared on both treatments, there were some differences on the suitable condition to store the ginger rhizome where the rhizome can sustain its water content prior to storage.

Here, we can clearly see that the ginger that stored in15±1°C; 90±2% treatment have better water content percentage rather than the ginger that stored in 75±2% humidity treatment at the same temperature. The similar trend line as the 90±2% humidity treatment was obtained at 15±1°C; 80±2% treatment, but the trend was placed lower than 15±1°C; 90±2% treatment trend line. Even so, the differences in the range of the water content percentage between these lines were small thus conclude that the ginger rhizome can be stored in either at 15±1°C with 90±2% humidity or at 15±1°C with 80±2% humidity in order to maintain the ginger rhizomes' water content.

Figure 4.6 (C) shows the water content percentage of the ginger stored at 25±1°C temperature with certain humidity. All treatments showed consistent trends except for the 25±1°C; 75±2% treatment. At 25±1°C; 75±2% treatment, the trend was inclining on the first week but declined until the third week. After the third week, the water content percentage was increasing until the fourth week. At 25±1°C;

90±2%, the obtained trend line was on the peak at Week 1 and 3 and dropped at Week 2 and 4. The same trend was obtained at 15±1°C; 82±2% treatment, with three values of water content percentage during Week 2 and 4 are quite same and some slight differences during Week 1 and 3. Here, we can say that in 25±1°C, there were no visible differences between the storage humidity since the value of water content percentages were not varies too much at each other. The ginger can be stored in this temperature at any humidity condition.

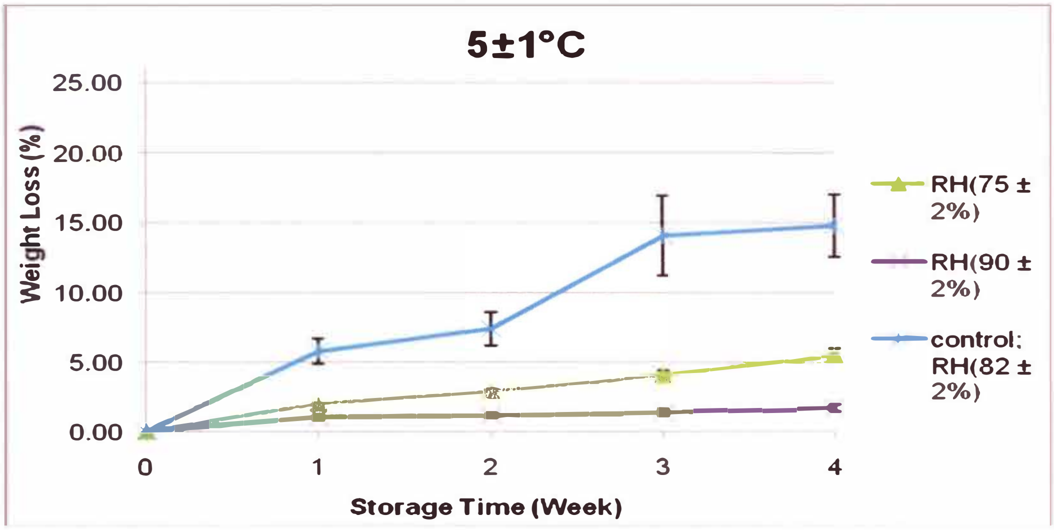
The statistical analysis with Tukey test on the water content percentage of ginger was done after the analysis was finished (Appendix J). From the statistical evaluation by the temperature and humidity treatments; there was no significant difference between all treatments done. There was also the same result when the statistical evaluation by the storage time; no significant difference between the treatments effect on the water content percentage of ginger. Based on the analysis, the least water content changes was at 5±1°C; 90±2% treatment where the ginger rhizome's water content percentage was not influenced by all treatments, thus there were no differences on where the rhizome were stored, respectively.

4.7. Percentage of weight loss

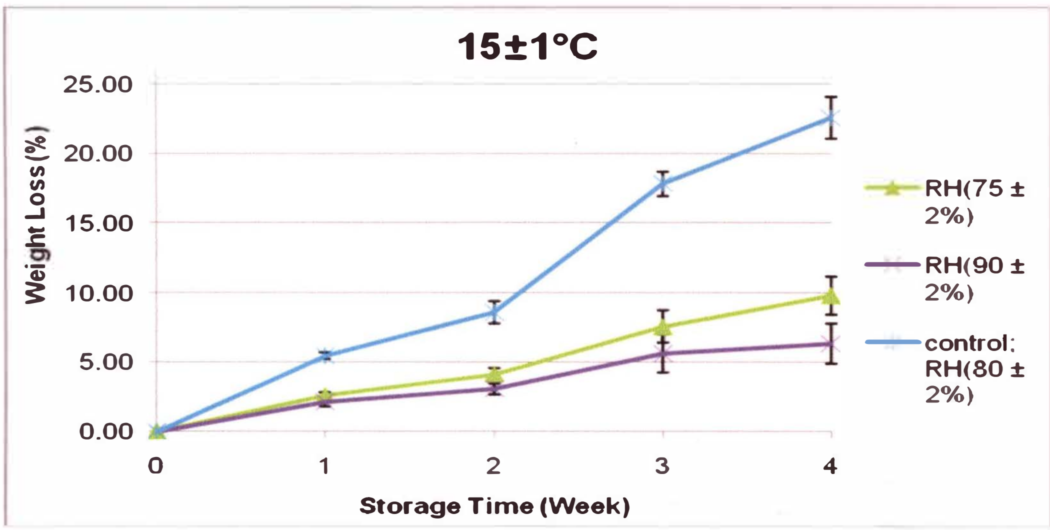
The percentage of weight loss assessment was done by storing the rhizome in the selected temperature and humidity, and weighs the rhizome once a week in experiment week. The smaller the percentage of weight loss, the best was the storage condition. It was because if the weight loss of a produce is larger than 5% during storage, the produce will be low in the market price and not a highly price crop.

The obtained graph on Figure 4.7 (A) shows the weight loss percentage of the ginger stored at respective temperature and humidity. All treatments showed consistent trends. At 5±1°C; 75±2% treatment and 5±1°C; 90±2% treatment, both trend lines has shown the same trend, nearly constant trend which were low than 5%. All weight loss percentage values were increasing from Week 0 until at the end of experiment. At 5±1°C; 82±2% treatment, the trend line was increasing with large difference between the value between Week 0 to Week 1 and between Week 2 and Week 3. Slight increases were available between Week 1 and 2, and between Week 3 and 4. This treatment had caused the ginger rhizome to loose its weight about 15%. Here, we can explain that the weight loss in the ginger stored had caused by the air movement factor that surrounds the ginger more than caused by storage temperature and humidity factor.

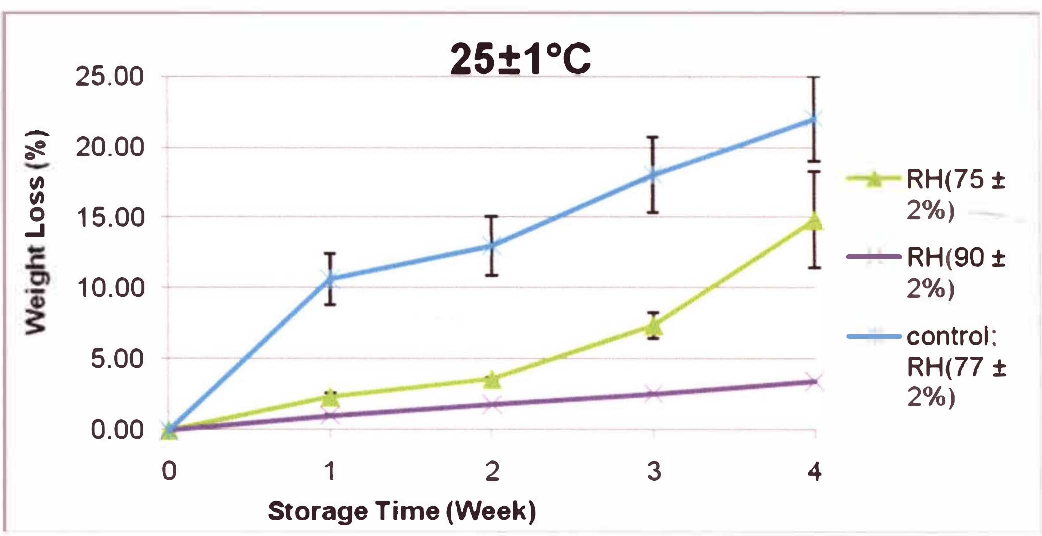
Figure 4.7 (B) shows the weight loss percentage of the ginger stored at 15±1°C temperature and certain humidity. All treatments showed consistent inclining trends but there were no constant trends available in this graph. At 15±1°C; 75±2% and 15±1°C; 90±2% treatment, the percentage obtained was not largely differ between these two treatments which increasing from Week 0 to the end of the experiment, with the treatment of 15±1°C; 75±2% has ended the experiment with higher percentage of weight loss more than the 15±1°C; 90±2% treatment. Even so, both treatments had because the ginger stored to loose more than 5% weight after four weeks of storage. At 15±1°C; 82±2% treatment, the trend line was increasing with large difference between the values at each week, causes more losses percentage up to 23% compared to other treatment. There was a huge difference between Week 2 and Week 3 in this treatment which has been caused by fungal infections on the rhizome stored added with the air velocity effects factor in the storage area.



(A)



(B)



(C)

Figure 4.7: The weight loss percentage of ginger stored at (A) 5±1°C; (B) 15±1°C; (C) 25±1°C at different relative humidity

Figure 4.7 (C) shows the weight loss percentage of the ginger stored at 25±1°C temperature and humidity. All treatments showed consistent trends. At 15±1°C; 75±2, the percentage of weight loss obtained was not largely differ in the early of experiment until it increased largely from Week 2 to Week 3 and Week 4 and cause the treatment of 15±1°C; 75±2% has ended the experiment with higher percentage of weight loss which were about 15%. The percentage was a lot than the 15±1°C; 90±2% treatment which was constant from Week 0 to the end of experiment with only about 4% weight loss. At 15±1°C; 82±2% treatment, the trend line was increasing with large difference between the values at each week, causes more losses percentage compared to other treatment especially between initial days to Week 1. The loss was mostly probably because of air movement which was dryer than in the closed container storage.

Statistical analysis with Tukey test on the percentage weight loss of ginger was done after the analysis was completed (Appendix K). From the statistical evaluation by the temperature and humidity treatments; there was no significant difference between all the treatments on Week 0 in term of weight loss percentage. However, at the 5±1°C; 75±2% treatment, the results on the weight loss percentage at Week 4 was significantly higher if compared to Week 1, 2 and 3. At 5±1°C; 90±2% treatment, there were no significant between the week assessed. At 5±1°C; 82±2% treatment, the results on the weight loss percentage at Week 4 was significantly higher if compared to Week 1, 2 and 3; even between Week 1, 2 and 3, there were no significant either.

On the statistical evaluation by the storage time, there was no significant difference between all treatments done on Week 1 if compared to the other weeks. However, on Week 0, 2, 3 and 4, the percentage weight loss of each treatment started to show differences among each other. At 25±1°C; 90±2% treatment, the percentage weight loss value was significantly higher if compared to the other treatments on the mentioned week above. This indicating that the treatment had undergone some increasing in percentage weight loss values, where the metabolic activities in the rhizomes increase due to higher temperature and humidity. This had caused the organic acids and starch in the rhizomes converted to the sugar to produce new buds. Based on the analysis, the least water content changes was at 5±1°C; 90±2% treatment where the ginger rhizome's water content percentage was not influenced by all treatments, thus there were no differences on where the rhizome were stored, respectively.

CHAPTER 5

CONCLUSIONS

5.1. Conclusion

The storage of ginger (*Zingiber officinale* Roscoe) in different temperature and humidity has been conducted for four weeks with seven parameter measurements. The parameters were firmness, total colour changes on skin, total colour changes on flesh, pH, total soluble solid, water content and percentage weight loss. After conducting the experiment, there was a found that the firmness, flesh lightness, skin redness and water content of the ginger were not affected by different storage temperature and humidity. In the other hand, the stored ginger had changed in total soluble solid, skin lightness, flesh redness (a* value), flesh yellowness (b* value), skin yellowness (b* value), pH and weight loss.

The total soluble solid had significant value at 25±1°C; 90±2% treatment while the other treatments have not shows any significant value at all. The skin lightness of ginger had significant value at 5±1°C; 90±2% treatment; flesh redness at 25±1°C; 90±2% and 25±1°C; 75±2% treatments with other treatments had no significant difference; flesh yellowness lowest significant at 15±1°C; 75±2% treatment; skin yellowness lowest significant at 15±1°C; 80±2% treatment; pH at 5±1°C; 82±2% treatment; and weight loss lowest significant at 5±1°C; 90±2% treatment. The lower significant differences or no significant difference at all treatments in colour changes were needed since the colour changes indicated the maturity of the produce. The changed in lightness to the higher value shows that the ginger become duller because the colour pigment had degraded into organic acids to produce buds. To achieve the best quality, the ginger physiology and behaviour should not changed by storage treatment. Here, the best treatment for ginger storage temperature and humidity is 5±1 °C with 90±2% relative humidity.

5.2. Suggestions for further study

As for the recommendation which related to this study, some modifications and analyses should also be added in order to investigate the more effects on different application of storage method of the ginger rhizome. More parameters and treatments should be tested for a wide observation of the compositional changes in the ginger due to storage time and treatment. Since the ginger rhizome can be stored more than a month, the suitable experiment period should be determined. This is very important in determining the quality of the ginger and to analyze the market potential of this produce locally as well as internationally.

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APPENDIX A

The firmness of ginger stored at different storage conditions

Storage Conditions	Firmness				
	Week 0	Week 1	Week 2	Week 3	Week 4
5±1°C; 75±2%	1.18E3 ± 80.11^{Aa}	1.29E3 ± 113.32^{Aa}	1.21E3 ± 138.45^{Aa}	1.13E3 ± 120.12^{Aa}	1.12E3 ± 145.27^{Aa}
5±1°C; 90±2%	1.26E3 ± 208.32^{Aa}	1.22E3 ± 44.77^{Aa}	1.16E3 ± 22.00^{Aa}	1.17E3 ± 23.31^{Aa}	1.20E3 ± 323.93^{Aa}
5±1°C; 82±2%	1.22E3 ± 98.81^{Aa}	1.26E3 ± 54.39^{Aa}	1.11E3 ± 109.74^{Aa}	1.17E3 ± 109.11^{Aa}	1.07E3 ± 60.12^{Aa}
15±1°C; 75±2%	1.40E3 ± 77.56^{Aa}	1.17E3 ± 35.49^{Aa}	1.21E3 ± 119.83^{Aa}	1.33E3 ± 191.34^{Aa}	1.30E3 ± 194.54^{Aa}
15±1°C; 90±2%	1.38E3 ± 145.33^{Aa}	1.29E3 ± 197.48^{Aa}	1.18E3 ± 153.68^{Aa}	1.29E3 ± 149.40^{Aa}	1.21E3 ± 137.73^{Aa}
15±1°C; 80±2%	1.30E3 ± 94.56^{Aa}	1.22E3 ± 82.68^{Aa}	1.30E3 ± 31.94^{Aa}	1.32E3 ± 162.34^{Aa}	1.15E3 ± 11.29^{Aa}
25±1°C; 75±2%	1.16E3 ± 58.74^{Aa}	1.18E3 ± 70.56^{Aa}	1.26E3 ± 72.58^{Aa}	1.09E3 ± 45.36^{Aa}	1.06E3 ± 130.07^{Aa}
25±1°C; 90±2%	1.17E3 ± 106.94^{Aa}	1.20E3 ± 82.47^{Aa}	1.27E3 ± 67.66^{Aa}	1.08E3 ± 90.24^{Aa}	1.12E3 ± 68.29^{Aa}
25±1°C; 77±2%	1.12E3 ± 102.12^{Aa}	1.13E3 ± 166.78^{Aa}	1.23E3 ± 58.11^{Aa}	1.04E3 ± 101.72^{Aa}	1.04E3 ± 115.56^{Aa}

Note: Values in Appendix A are mean of 3 replicates (4 representative samples/replicate) mean (n=12) ± standard deviation
A: Means bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)
a: Means bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)

APPENDIX B

The L* value of the skin of ginger stored at different storage conditions

Storage Conditions	L* value of skin				
	Week 0	Week 1	Week 2	Week 3	Week 4
5±1°C; 75±2%	67.35 ± 1.93^{Aa}	63.76 ± 3.51^{Aa}	63.07 ± 2.09^{Aa}	68.04 ± 2.30^{Aa}	66.07 ± 2.14^{Aa}
5±1°C; 90±2%	68.53 ± 2.58^{Aa}	62.69 ± 3.06^{Aa}	62.04 ± 5.14^{Aa}	65.93 ± 1.93^{Aa}	68.10 ± 1.08^{Aa}
5±1°C; 82±2%	69.39 ± 1.01^{Abc}	64.66 ± 1.67^{Aa}	65.38 ± 2.17^{Aab}	69.95 ± 1.82^{Ac}	71.27 ± 0.51^{Ac}
15±1°C; 75±2%	68.27 ± 4.41^{Aa}	66.59 ± 7.04^{Aa}	61.19 ± 1.23^{Aa}	64.11 ± 6.65^{Aa}	60.59 ± 14.79^{Aa}
15±1°C; 90±2%	67.70 ± 0.99^{Aa}	67.65 ± 1.96^{Aa}	62.83 ± 4.66^{Aa}	65.27 ± 6.75^{Aa}	66.22 ± 7.12^{Aa}
15±1°C; 80±2%	68.01 ± 1.85^{Aa}	66.23 ± 2.98^{Aa}	62.69 ± 2.67^{Aa}	63.97 ± 8.24^{Aa}	64.91 ± 6.06^{Aa}
25±1°C; 75±2%	62.34 ± 3.56^{Aa}	62.45 ± 3.12^{Aa}	66.12 ± 1.75^{Aa}	68.76 ± 2.84^{Aa}	67.29 ± 1.64^{Aa}
25±1°C; 90±2%	61.21 ± 2.67^{Aa}	63.59 ± 4.36^{Aa}	62.66 ± 1.02^{Aa}	67.47 ± 4.49^{Aa}	64.89 ± 4.33^{Aa}
25±1°C; 77±2%	61.51 ± 4.88^{Aa}	66.45 ± 1.03^{Aa}	66.11 ± 2.34^{Aa}	68.59 ± 2.87^{Aa}	68.39 ± 1.95^{Aa}

Note: Values in Appendix B are mean of 3 replicates (4 representative samples/replicate) mean (n=12) ± standard deviation
A: Means bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)
a: Means bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)

APPENDIX C

The a* value of the skin of ginger stored at different storage conditions

Storage Conditions	a* value of skin				
	Week 0	Week 1	Week 2	Week 3	Week 4
5±1°C; 75±2%	4.32 ± 0.91^{Aa}	4.47 ± 0.35^{Aa}	5.37 ± 1.19^{Aa}	4.66 ± 1.22^{Aa}	5.42 ± 1.07^{Aa}
5±1°C; 90±2%	4.11 ± 0.43^{Aa}	4.10 ± 0.53^{Aa}	5.51 ± 1.02^{Aa}	4.57 ± 0.53^{Aa}	4.43 ± 0.74^{Aa}
5±1°C; 82±2%	3.73 ± 0.31^{Aa}	4.11 ± 0.87^{Aa}	5.27 ± 1.23^{Aa}	4.84 ± 0.81^{Aa}	4.63 ± 1.19^{Aa}
15±1°C; 75±2%	4.42 ± 1.22^{Aa}	4.19 ± 1.26^{Aa}	5.22 ± 0.47^{Aa}	4.05 ± 1.98^{Aa}	3.50 ± 1.74^{Aa}
15±1°C; 90±2%	4.24 ± 1.77^{Aa}	4.32 ± 1.91^{Aa}	4.26 ± 0.39^{Aa}	3.36 ± 1.11^{Aa}	3.08 ± 1.99^{Aa}
15±1°C; 80±2%	4.35 ± 1.32^{Aa}	4.75 ± 1.78^{Aa}	4.76 ± 0.51^{Aa}	4.60 ± 2.70^{Aa}	3.86 ± 2.00^{Aa}
25±1°C; 75±2%	4.45 ± 0.35^{Aa}	4.20 ± 0.66^{Aa}	3.54 ± 0.99^{Aa}	2.53 ± 0.46^{Aa}	4.81 ± 1.81^{Aa}
25±1°C; 90±2%	4.89 ± 1.18^{Aa}	3.75 ± 0.89^{Aa}	4.14 ± 1.36^{Aa}	3.24 ± 0.21^{Aa}	4.57 ± 1.08^{Aa}
25±1°C; 77±2%	5.06 ± 0.83^{Aa}	5.39 ± 1.19^{Aa}	4.32 ± 0.56^{Aa}	3.16 ± 0.76^{Aa}	4.56 ± 0.84^{Aa}

Note: Values in Appendix C are mean of 3 replicates (4 representative samples/replicate) mean (n=12) ± standard deviation
A: Means bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)
a: Means bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)

APPENDIX D

The b* value of the skin of ginger stored at different storage conditions

Storage Conditions	b* value				
	Week 0	Week 1	Week 2	Week 3	Week 4
5±1°C; 75±2%	17.64 ± 0.74^{Aab}	18.82 ± 0.41^{Cab}	21.64 ± 3.01^{Ab}	16.75 ± 1.45^{BCa}	17.02 ± 1.69^{ABCa}
5±1°C; 90±2%	18.52 ± 2.47^{Aa}	20.36 ± 2.87^{Ca}	21.18 ± 1.25^{Aa}	17.38 ± 1.27^{Ca}	16.75 ± 1.21^{ABCa}
5±1°C; 82±2%	17.59 ± 3.22^{Aa}	18.51 ± 1.89^{BCa}	19.32 ± 4.08^{Aa}	17.30 ± 2.14^{Ca}	16.78 ± 1.09^{ABCa}
15±1°C; 75±2%	14.65 ± 2.08^{Aab}	14.26 ± 0.98^{ABa}	19.24 ± 1.71^{Ab}	14.73 ± 2.63^{ABCab}	12.88 ± 0.73^{Aa}
15±1°C; 90±2%	15.99 ± 3.26^{Aab}	14.10 ± 0.48^{Aab}	18.13 ± 0.22^{Ab}	13.18 ± 1.01^{ABCa}	13.03 ± 1.35^{ABa}
15±1°C; 80±2%	15.98 ± 3.06^{Aa}	13.49 ± 1.25^{Aa}	17.54 ± 1.96^{Aa}	13.75 ± 2.25^{ABCa}	13.72 ± 1.45^{ABCa}
25±1°C; 75±2%	19.02 ± 2.96^{Ab}	17.07 ± 1.38^{ABCab}	17.22 ± 2.84^{Aab}	11.53 ± 1.55^{Aa}	17.07 ± 1.52^{BCab}
25±1°C; 90±2%	17.65 ± 0.57^{Ab}	19.69 ± 2.03^{Cb}	17.65 ± 2.81^{Ab}	12.36 ± 1.65^{ABa}	17.85 ± 0.61^{Cb}
25±1°C; 77±2%	18.63 ± 0.42^{Ab}	15.99 ± 0.76^{Cb}	15.99 ± 0.82^{Ab}	11.63 ± 0.56^{Aa}	16.70 ± 2.53^{ABCb}

Note: Values in Appendix D are mean of 3 replicates (4 representative samples/replicate) mean (n=12) ± standard deviation
A-C: Means bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)
a-b: Means bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)

APPENDIX E

The L* value of the flesh of ginger stored at different storage conditions

Storage Conditions	**L* value of flesh**				
	Week 0	**Week 1**	**Week 2**	**Week 3**	**Week 4**
5±1°C; 75±2%	74.64 ± 3.02^{Aa}	72.61 ± 4.84^{Aa}	75.34 ± 3.17^{Aa}	71.19 ± 2.76^{Aa}	70.68 ± 1.88^{Aa}
5±1°C; 90±2%	76.46 ± 3.73^{Aa}	76.35 ± 1.90^{Aa}	74.18 ± 0.88^{Aa}	73.53 ± 3.55^{Aa}	71.35 ± 9.67^{Aa}
5±1°C; 82±2%	72.82 ± 6.96^{Aa}	75.63 ± 4.37^{Aa}	71.94 ± 2.13^{Aa}	72.64 ± 1.86^{Aa}	73.67 ± 3.74^{Aa}
15±1°C; 75±2%	71.27 ± 2.60^{Aa}	72.19 ± 2.68^{Aa}	67.24 ± 10.25^{Aa}	70.93 ± 2.93^{Aa}	70.22 ± 3.40^{Aa}
15±1°C; 90±2%	69.16 ± 1.90^{Aa}	72.19 ± 0.74^{Aa}	71.49 ± 3.97^{Aa}	69.01 ± 3.55^{Aa}	69.37 ± 1.36^{Aa}
15±1°C; 80±2%	71.29 ± 3.67^{Aa}	71.37 ± 3.13^{Aa}	72.65 ± 3.68^{Aa}	70.84 ± 3.52^{Aa}	72.28 ± 4.55^{Aa}
25±1°C; 75±2%	70.46 ± 4.12^{Aa}	74.12 ± 2.95^{Aa}	74.31 ± 2.35^{Aa}	74.51 ± 5.29^{Aa}	71.90 ± 1.85^{Aa}
25±1°C; 90±2%	72.08 ± 4.84^{Aa}	68.71 ± 6.02^{Aa}	73.45 ± 2.31^{Aa}	72.19 ± 3.30^{Aa}	72.71 ± 4.09^{Aa}
25±1°C; 77±2%	69.27 ± 4.40^{Aa}	69.59 ± 5.70^{Aa}	72.86 ± 2.34^{Aa}	73.67 ± 4.96^{Aa}	72.41 ± 1.55^{Aa}

Note: Values in Appendix E are mean of 3 replicates (4 representative samples/replicate) mean (n=12) ± standard deviation
A: Means bearing the same superscript within the same row are not significantly different at 5% level (p<0.05)
a: Means bearing the same superscript within the same column are not significantly different at 5% level (p<0.05)

APPENDIX F

The a* value of the flesh of ginger stored at different storage conditions

Storage Conditions	a* value of flesh				
	Week 0	Week 1	Week 2	Week 3	Week 4
5±1°C; 75±2%	-4.60 ± 1.00^{Aa}	-3.68 ± 2.10^{Aa}	-4.75 ± 1.17^{Aa}	-3.93 ± 0.79^{Aa}	-4.57 ± 0.28^{Aa}
5±1°C; 90±2%	-4.63 ± 0.39^{Aa}	-5.61 ± 0.66^{Aa}	-4.67 ± 1.20^{Aa}	-4.20 ± 0.85^{Aa}	-3.76 ± 1.64^{Aa}
5±1°C; 82±2%	-4.53 ± 0.94^{Aa}	-4.63 ± 1.24^{Aa}	-4.52 ± 1.71^{Aa}	-4.22 ± 1.21^{Aa}	-4.34 ± 0.77^{Aa}
15±1°C; 75±2%	-2.74 ± 2.00^{Aa}	-4.12 ± 1.48^{Aa}	-5.60 ± 2.43^{Aa}	-4.88 ± 2.89^{Aa}	-4.62 ± 2.49^{Aa}
15±1°C; 90±2%	-2.71 ± 2.60^{Aa}	-3.74 ± 0.41^{Aa}	-4.89 ± 3.11^{Aa}	-4.57 ± 2.95^{Aa}	-5.45 ± 2.50^{Aa}
15±1°C; 80±2%	-2.98 ± 2.00^{Aa}	-3.81 ± 0.35^{Aa}	-4.83 ± 3.74^{Aa}	-4.56 ± 3.64^{Aa}	-3.22 ± 2.77^{Aa}
25±1°C; 75±2%	-3.94 ± 0.66^{Ab}	-4.82 ± 0.77^{Aab}	-4.77 ± 0.26^{Aab}	-6.86 ± 1.98^{Aa}	-4.20 ± 0.69^{Aab}
25±1°C; 90±2%	-4.37 ± 0.87^{Ab}	-4.89 ± 0.90^{Aa}	-4.86 ± 0.21^{Aab}	-6.70 ± 0.57^{Aa}	-4.32 ± 0.83^{Aa}
25±1°C; 77±2%	-3.31 ± 1.50^{Aa}	-3.49 ± 1.68^{Aa}	-4.23 ± 1.75^{Aa}	-6.17 ± 1.31^{Aa}	-3.96 ± 1.22^{Aa}

Note: Values in Appendix F are mean of 3 replicates (4 representative samples/replicate) mean (n=12) ± standard deviation
A: Means bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)
a-b: Means bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)

APPENDIX G

The b* value of the flesh of ginger stored at different storage conditions

Storage Conditions	b* value of flesh				
	Week 0	Week 1	Week 2	Week 3	Week 4
5±1°C; 75±2%	30.22 ± 2.92^{ABa}	27.00 ± 8.78^{Aa}	28.56 ± 4.11^{Aa}	28.31 ± 3.09^{ABa}	27.31 ± 0.98^{Aa}
5±1°C; 90±2%	31.79 ± 2.77^{Ba}	29.94 ± 2.58^{Aa}	27.84 ± 2.01^{Aa}	29.77 ± 2.97^{Ba}	27.98 ± 7.45^{Aa}
5±1°C; 82±2%	29.25 ± 3.56^{ABa}	29.09 ± 3.32^{Aa}	27.70 ± 5.53^{Aa}	28.50 ± 3.89^{ABa}	27.54 ± 3.44^{Aa}
15±1°C; 75±2%	22.00 ± 2.15^{ABa}	23.46 ± 2.64^{Aa}	24.08 ± 3.56^{Aa}	21.36 ± 0.28^{ABa}	23.36 ± 4.37^{Aa}
15±1°C; 90±2%	24.20 ± 2.14^{ABa}	21.34 ± 2.35^{Aa}	23.27 ± 2.06^{Aa}	20.93 ± 2.19^{Aa}	23.89 ± 1.74^{Aa}
15±1°C; 80±2%	24.27 ± 2.90^{ABa}	22.71 ± 3.19^{Aa}	23.44 ± 0.61^{Aa}	23.15 ± 0.51^{ABa}	24.20 ± 1.13^{Aa}
25±1°C; 75±2%	31.16 ± 3.06^{ABa}	29.02 ± 3.90^{Aa}	29.75 ± 5.77^{Aa}	24.88 ± 3.81^{ABa}	28.09 ± 1.08^{Aa}
25±1°C; 90±2%	30.04 ± 6.12^{ABa}	24.22 ± 2.53^{Aa}	28.62 ± 0.63^{Aa}	23.52 ± 4.27^{ABa}	28.82 ± 4.33^{Aa}
25±1°C; 77±2%	24.24 ± 1.55^{ABa}	25.68 ± 5.43^{Aa}	28.18 ± 5.02^{Aa}	20.40 ± 3.60^{Aa}	31.13 ± 7.00^{Aa}

Note: Values in Appendix G are mean of 3 replicates (4 representative samples/replicate) mean (n=12) ± standard deviation
A-B: Means bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)
a: Means bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)

APPENDIX H

The pH of ginger stored at different storage conditions

Storage Conditions	pH value				
	Week 0	Week 1	Week 2	Week 3	Week 4
5±1°C; 75±2%	6.46 ± 0.68^{Aa}	6.57 ± 0.15^{Aa}	6.69 ± 0.18^{Aa}	7.05 ± 0.17^{Aa}	6.71 ± 0.09^{ABa}
5±1°C; 90±2%	6.24 ± 0.72^{Aa}	6.52 ± 0.18^{Aa}	6.69 ± 0.20^{Aa}	6.86 ± 0.18^{Aa}	6.62 ± 0.16^{ABa}
5±1°C; 82±2%	6.12 ± 0.22^{Aa}	6.43 ± 0.12^{Aab}	6.42 ± 0.19^{Aab}	6.73 ± 0.11^{Ab}	6.57 ± 0.24^{ABab}
15±1°C; 75±2%	6.76 ± 0.13^{Aa}	6.77 ± 0.46^{Aa}	6.92 ± 0.72^{Aa}	7.05 ± 0.89^{Aa}	7.74 ± 0.29^{Ba}
15±1°C; 90±2%	6.80 ± 0.14^{Aa}	6.83 ± 0.38^{Aa}	7.12 ± 0.84^{Aa}	7.03 ± 0.92^{Aa}	7.88 ± 0.02^{Ba}
15±1°C; 80±2%	6.88 ± 0.19^{Aa}	6.65 ± 0.18^{Aa}	6.79 ± 0.50^{Aa}	7.10 ± 1.08^{Aa}	7.81 ± 0.27^{Ba}
25±1°C; 75±2%	6.47 ± 0.01^{Aa}	6.97 ± 0.78^{Aa}	6.55 ± 0.08^{Aa}	6.48 ± 0.27^{Aa}	6.48 ± 0.13^{ABa}
25±1°C; 90±2%	6.48 ± 0.05^{Aa}	7.40 ± 1.86^{Aa}	6.49 ± 0.09^{Aa}	6.46 ± 0.12^{Aa}	6.65 ± 0.19^{ABa}
25±1°C; 77±2%	6.42 ± 0.11^{Aa}	7.12 ± 2.53^{Aa}	6.60 ± 0.42^{Aa}	6.80 ± 0.34^{Aa}	6.04 ± 1.44^{Aa}

Note: Values in Appendix H are mean of 3 replicates (4 representative samples/replicate) mean (n=12) ± standard deviation
A-B: Means bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)
a-b: Means bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)

APPENDIX I

The total soluble solid of ginger stored at different storage conditions

Storage Conditions	Total Soluble Solid				
	Week 0	Week 1	Week 2	Week 3	Week 4
5±1°C; 75±2%	3.60 ± 0.53^{Aa}	3.83 ± 0.38^{Aa}	3.60 ± 0.53^{Aa}	3.87 ± 0.25^{Aa}	4.77 ± 1.33^{Aa}
5±1°C; 90±2%	3.17 ± 0.29^{Aa}	3.83 ± 0.64^{Aa}	3.27 ± 0.46^{Aa}	3.80 ± 0.20^{Aa}	3.50 ± 0.50^{Aa}
5±1°C; 82±2%	3.93 ± 0.12^{Aa}	4.00 ± 0.10^{Aa}	3.53 ± 0.50^{Aa}	4.33 ± 0.58^{Aa}	3.39 ± 0.06^{Aa}
15±1°C; 75±2%	5.33 ± 2.47^{Aa}	5.37 ± 2.41^{Aa}	5.53 ± 2.25^{Aa}	5.80 ± 2.10^{Aa}	5.23 ± 1.52^{Aa}
15±1°C; 90±2%	5.30 ± 1.74^{Aa}	5.77 ± 2.41^{Aa}	5.27 ± 2.22^{Aa}	5.00 ± 1.59^{Aa}	4.30 ± 1.01^{Aa}
15±1°C; 80±2%	5.33 ± 2.03^{Aa}	5.90 ± 2.27^{Aa}	5.73 ± 1.59^{Aa}	6.47 ± 2.41^{Aa}	5.50 ± 1.30^{Aa}
25±1°C; 75±2%	2.83 ± 0.49^{Aa}	2.53 ± 0.45^{Aa}	3.13 ± 0.35^{Aa}	3.13 ± 0.15^{Aa}	3.20 ± 0.20^{Aa}
25±1°C; 90±2%	3.17 ± 0.47^{Aab}	2.40 ± 0.52^{Aa}	3.13 ± 0.15^{Aab}	3.00 ± 0.10^{Aab}	3.37 ± 0.31^{Ab}
25±1°C; 77±2%	2.83 ± 0.45^{Aa}	2.70 ± 0.61^{Aa}	3.37 ± 0.55^{Aa}	3.30 ± 0.80^{Aa}	3.63 ± 0.49^{Aa}

Note: Values in Appendix I are means of 3 replicates (4 representative samples/replicate) mean (n=12) ± standard deviation
A: Means bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)
a-b: Means bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)

APPENDIX J

The water content of ginger stored at different storage conditions

Storage Conditions	Water Content (%)				
	Week 0	Week 1	Week 2	Week 3	Week 4
5±1°C; 75±2%	95.10 ± 0.18^{Aa}	94.24 ± 1.07^{Aa}	93.84 ± 2.27^{Aa}	95.41 ± 0.26^{Aa}	93.85 ± 1.79^{Aa}
5±1°C; 90±2%	94.63 ± 1.65^{Aa}	93.81 ± 1.35^{Aa}	93.88 ± 0.87^{Aa}	94.84 ± 0.83^{Aa}	95.09 ± 1.54^{Aa}
5±1°C; 82±2%	94.56 ± 1.46^{Aa}	93.84 ± 1.43^{Aa}	94.41 ± 0.68^{Aa}	94.39 ± 0.62^{Aa}	94.70 ± 0.49^{Aa}
15±1°C; 75±2%	95.03 ± 2.09^{Aa}	95.22 ± 1.25^{Aa}	94.33 ± 1.84^{Aa}	94.30 ± 1.99^{Aa}	93.05 ± 5.05^{Aa}
15±1°C; 90±2%	95.52 ± 0.51^{Aa}	94.04 ± 2.09^{Aa}	94.43 ± 1.63^{Aa}	94.85 ± 1.65^{Aa}	94.97 ± 0.89^{Aa}
15±1°C; 80±2%	77.98 ± 28.56^{Aa}	93.66 ± 1.51^{Aa}	93.98 ± 1.80^{Aa}	92.92 ± 2.03^{Aa}	93.61 ± 1.95^{Aa}
25±1°C; 75±2%	95.07 ± 1.13^{Aa}	96.18 ± 1.11^{Aa}	95.52 ± 1.91^{Aa}	94.88 ± 0.46^{Aa}	95.51 ± 0.29^{Aa}
25±1°C; 90±2%	93.96 ± 0.20^{Aa}	96.19 ± 1.80^{Aa}	94.69 ± 1.42^{Aa}	95.42 ± 1.11^{Aa}	94.67 ± 1.67^{Aa}
25±1°C; 77±2%	94.70 ± 0.64^{Aa}	96.48 ± 1.51^{Aa}	94.43 ± 0.89^{Aa}	95.22 ± 1.77^{Aa}	94.60 ± 1.05^{Aa}

Note: Values in Appendix J are mean of 3 replicates; mean (n=3) ± standard deviation
A: Means bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)
a: Means bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)

APPENDIX K

The percentage of weight loss of ginger stored at different storage conditions

Storage Conditions	Weight Loss (%)				
	Week 0	Week 1	Week 2	Week 3	Week 4
5±1°C; 75±2%	0.00 ± 0.00^{Aa}	1.98 ± 0.37^{Aab}	2.86 ± 0.72^{Ab}	4.08 ± 0.98^{ABbc}	5.53 ± 1.50^{ABCc}
5±1°C; 90±2%	0.00 ± 0.00^{Aa}	1.06 ± 0.68^{Aa}	1.14 ± 0.61^{Aa}	1.38 ± 0.74^{Aa}	1.68 ± 0.82^{Aa}
5±1°C; 82±2%	0.00 ± 0.00^{Aa}	5.77 ± 3.08^{ABa}	7.41 ± 4.19^{ABa}	14.07 ± 9.84^{ABa}	14.80 ± 7.65^{ABCa}
15±1°C; 75±2%	0.00 ± 0.00^{Aa}	2.58 ± 0.84^{Aab}	4.15 ± 1.54^{Aab}	7.56 ± 3.99^{ABab}	9.81 ± 4.66^{ABCb}
15±1°C; 90±2%	0.00 ± 0.00^{Aa}	2.14 ± 1.17^{Aa}	3.06 ± 1.43^{Aa}	5.62 ± 4.64^{ABa}	6.36 ± 5.03^{ABCa}
15±1°C; 80±2%	0.00 ± 0.00^{Aa}	5.48 ± 0.93^{ABab}	8.58 ± 2.84^{ABb}	17.80 ± 3.02^{Bc}	22.56 ± 5.37^{Cc}
25±1°C; 75±2%	0.00 ± 0.00^{Aa}	2.37 ± 1.04^{Aab}	3.62 ± 0.45^{Aab}	7.38 ± 3.21^{ABab}	14.84 ± 11.86^{ABCb}
25±1°C; 90±2%	0.00 ± 0.00^{Aa}	1.03 ± 0.24^{Ab}	1.82 ± 0.08^{Ac}	2.57 ± 0.14^{Ad}	3.45 ± 0.11^{ABe}
25±1°C; 77±2%	0.00 ± 0.00^{Aa}	10.62 ± 6.28^{Bab}	12.99 ± 7.37^{Bab}	18.03 ± 7.49^{Bab}	22.03 ± 10.43^{BCb}

Note: Values in Appendix K are means of 3 replicates; mean (n=3) ± standard deviation
A-C: Means bearing the same superscript within the same column are not significantly different at 5% level ($p<0.05$)
a-e: Means bearing the same superscript within the same row are not significantly different at 5% level ($p<0.05$)

CURRICULUM VITAE (CV)

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2004 – 2007	: KOLEJ UNIVERSITI SAINS DAN TEKNOLOGI MALAYSIA (KUSTEM) Diploma of Fisheries (CGPA: 3.37)
2002 – 2003	: SEK. MEN. KEB. KAMIL, KELANTAN (SPM: 2 1A, 2 2A, 2 3B, 2 4B, 2 6C)
1999 – 2002	: SEK. MEN. KEB. PENAREK, TERENGGANU (PMR: 6A, 2B)

EXPERIENCE / SKILLS

- Experience in breeding and producing of *Clarias gariepinus* (Keli) in Practical Aquaculture subject, diploma study.
- Experience in farming of *Lates calcarifer* (Siakap) in Practical Aquaculture subject, diploma study.
- Experience in farming of *Oreochimus niloticus* (Tilapia) and GIFT (*Genetic Improvement for Farmed Tilapia*) in Industrial Training, diploma study.
- Speaking language: Malay, English and some Japanese
- Have certificate in Microsoft Office 2000
- Good capability in using Internet, Microsoft Office 2003 and Microsoft Office 2007
- Experience in food processing of marine and freshwater fish products during Industrial Training, degree study.
- Good knowledge and greatly interesting in agrotechnology and post harvest technology sector, yet had furthered study in post harvest technology course.

CAREER OBJECTIVES

- Agrotechnology and post harvest sector, including processing of freshly harvest produces and physiology treatments of products.
- Administration and management in science of organization in educational institution.

WORKING EXPERIENCES

- Industrial Training at Pusat Penetasan Ikan Air Tawar (PPIAT), KADA, Kelantan in November 2006 – February 2007
- Industrial Training at Processing Department, Institut Perikanan Malaysia (IPM), Chendering, Terengganu in May – June 2009

CO-CURRICULAR ACTIVITIES

2009 – 2010	: Taking parts in Agribusiness Marketing Conference 2010, PWTC, Kuala Lumpur
2008 – 2009	: Taking parts in Kursus Asas Pemprosesan Ikan and Kursus Pemprosesan Ikan Ternakan, IPM, Terengganu.
2007 – 2008	: Taking parts in Kelab Usrah, Unit Kerohanian, UMT. Taking parts in Seminar Pencegahan Jenayah 2007, Terengganu. Taking parts in Seminar Keusahawanan 2008, UMT.

2004 – 2007	: AJK Sukan dan Rekreasi in Revolution of Fisheries Club (REVOF), KUSTEM
2002 – 2003	: Taking parts in SMK Kamil's English Debating Team, school representative.
1999 – 2001	: Taking parts in SMK Penarek's English Debating Team, school and district representative. AJK Keceriaan Kelab Bahasa Melayu 2001

EXPECTED SALARY

Expected salary: RM 1800

ACADEMIC REFEREES

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EFFECTS OF THE STORAGE TEMPERATURE AND HUMIDITY ON SHELF LIFE OF GINGER (ZINGIBER OFFICINALE ROSCOE) - ILI MAHIRAH BINTI MOHD JAMAL