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Postharvest Quality and Shelf Life of Ginger (*Zingiber officinale*) as Affected by Different Storage Methods

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Abstract: Prolonging the postharvest life of vegetable commodities is one of the primary concerns of farmers and traders. In the countryside, the objective in storage is not to keep the product for a long time but to lessen perishability so that the usefulness of the product is maximized and a larger profit can be derived if the products are to be marketed. Low-temperature storage is said to be the most effective method of prolonging the postharvest life of the fruit and vegetables. Storage is another key issue to preserve and improve the quality of ginger. The availability of appropriate cold storage is essential to maintain its quality. This study was conducted to evaluate the postharvest behavior and quality changes of ginger during storage at different methods and to determine the shelf life of ginger during storage. Different storage methods such as ambient storage, evaporative cooling storage (EC), ground box storage, and modified atmosphere storage (MAP) were evaluated for the postharvest quality changes and shelf life of ginger rhizomes. Ground/soil storage significantly slowed the visual quality reduction of the stored ginger because of growth resumption. Ambient-stored ginger had the shortest shelf-life because of high weight loss and incidence of decay. High humidity inside the MAP and Evaporative Cooling (EC) lengthened the shelf life of stored ginger.

Keywords: Ginger rhizomes, Ambient storage, Evaporative Cooling storage (EC) Modified Atmosphere storage, ground box storage, and shelf life.

Introduction

Ginger (*Zingiber officinale*) belongs to the family Zingiberaceae. Ginger has been known to be the most widely used of all spices for flavoring purposes. Ginger which is popularly known as *"luya"* and *"kabasi"* in the Philippines is grown as an important spice crop. It can be used as a raw material in the production of beverages, perfumes, and medicines. Due to its penetrating flavor, it is largely used for cooking and the preparation of preserves, candy, and pickles (Paull et. al., 1998b).

Ginger is one of the earliest important spices in the western hemisphere, reported being a native of Southeast Asia (Paull et., al 1988b). The largest ginger-producing country is India, which produces about 5% of the world's total production and is the larger exporter (FAO, 2012). Ginger has a high medicinal value used in Allopathic and Hamdard medicine, and also widely used as spice in Bangladesh (Parry, 200) Ginger is a popular underground root crop widely grown throughout the country. Almost the entire ginger production volume is consumed domestically in limited quantities (www.ba.ars.usda.gov/hd66/contents.html). Due to its higher content of water (80%), raw ginger root has lower overall nutrients when expressed per 100 grams (Camacho and Brescia, 2009).

Ginger rhizome is used as a spice because of its aroma and pungency (Puall et al. 2012). The aroma of ginger is pleasant and spicy and its flavor is slightly bitter when mixed with food products like gingerbread and making of ginger cocktails (Pruthi, 2006). The quality of a final product of ginger is determined by both pre-harvest and postharvest factors. The most important factor is the cultivar grown

(ITDG, 2013). Pre-harvest factors including management practices and environmental influence postharvest quality. A diverse range of biotic and abiotic factors can alter the appearance of produce before harvest (Kader, 2002). The appropriate temperature relative humidity for storage of ginger is 12^0C and 75% RH. In this condition, the ginger can be stored for 3-4 months. Improper storage causes loss of weight, surface shriveling, sprouting of the rhizome, and infection of disease (USAID, 2004).

Preserving the quality of fruits after harvest depends largely on the environmental condition in storage. Lower temperature and higher relative humidity are generally required to reduce the rate of the deteriorative process such as respiration and transpiration and to improve the shelf life of produce (Bautista, 1990). Maintaining the quality and prolonging the usefulness of any crop to get better profit is the pressing problem in food production (Pantastico, 1977). Harvesting rhizomes successfully depends in large part on planting and the proper time for each location. The rhizome of the ginger plants is referred to as a root. Fibrous mature root has light yellowish-brown skin when fresh (Paull et al. 2012). Unwashed rhizome which may have a deteriorating physical appearance may also affect the whole quality of ginger during storage, packaging, and transportation. They may increase postharvest losses during this period (Chaudhary, 2008).

Prolonging the postharvest life of vegetable commodities is one of the primary concerns of farmers and traders. In the countryside, the objective in storage is not to keep the product for a long time but to lessen perishability so that the usefulness of the product is maximized and a larger profit can be derived if the crops are to be marketed (Bautista, 1982). Low-temperature storage is said to be the most effective method of prolonging the postharvest life of the fruit and vegetables.

However, the initial investment and operating cost of maintaining a refrigeration unit are very high and therefore not affordable to small farmers (Valdez and Araral, 1984). Handling of crop commodities is also an important consideration in prolonging postharvest life. Injuries due to faulty handling serve as the entry points of harmful microorganisms and the avenues for water loss (Bautista and Labios, 1983).

Storage is another key issue to preserve and improve the quality of ginger. The availability of appropriate cold storage is essential to maintain its quality. Ginger can be stored for a shorter period if not stored properly. The shelf life of peeled ginger can be extended to 2-3 months if stored at low temperatures. Among the storage method, cold storage has always been recommended due to its efficacy in extending commodity life over a long period. It was observed that produce stored at low temperatures has a longer storage life than those stored under ambient conditions (Bautista and Esguerra, 1903).

Evaporative cooling is another method of storage. It is simply defined as the adiabatic exchange of heat and water from wetted surfaces or applied in spray (Woolrich and Hallowel, 1970). This storage method relies not only on the reduction in temperature but largely on the increase in the RH in the storage environment (Andales and Lozada, 1980). One of the possibilities of extending the storage life of fruits is by reducing the incidence of decay and decreasing the respiration rate with the use of a controlled or modified atmosphere (Caygill et al. 1976). Fruits and vegetables such as banana, cucumber, tomatoes and pechay stored in evaporative coolers showed extended postharvest life as compared, to those hold under ordinary room conditions (Uy and Lizada, 1984; Olea, 1984; Buot, 1986; Granada, 1987; Reyes, 1990). Storage in a simple evaporative cooler, in a clay jar, or saturated sawdust and rice hull ash was also found to be effective in minimizing weight loss and shriveling in cucumber (Granada, 1987).

Modified atmosphere (MA) storage is similar to CA storage except that the O2 and high CO2 atmosphere is not under close regulation as illustrated in mango (Maker jee, 1961) and banana fruits (Scott and

Chandanegra, 1974). Modified atmosphere considerably prolonged the storage life. Fruits packed in sealed polyethylene bags and kept at 10 degrees Celsius prevented anthracnose. Softening was significantly delayed in avocado fruits wrapped in a polyethylene bag (Thompson et al. 1971). The storage life of "Hass" avocado, fruits packed in sealed polyethylene was extended because the decay caused by anthracnose was prevented (Ondit and Scott, 1973). Plastic film and bags to create a modified atmosphere have also been used in capsicum storage (Anadaswamy et. al., 1959). The main benefit of packing capsicums in the plastic film was on the reduction of water loss but they also found that that the fruit were decayed (Bussel and Kenigsberger, 1975). Other methods that inclusively inhibited the ripening process of fruit commodities include controlled and modified atmosphere storage, hypobaric storage, and chemical treatment (Pantastico, 1987).

These storage methods have not been widely employed particularly in rural areas due to their expensive nature and the scarcity of the materials needed. As a consequence, some alternative and inexpensive storage systems which utilized indigenous materials were developed (Nuyda and Bautista and Perido, 1982). Ambient storage is normally used by farmers. This storage is done in an ordinary room with prevalent temperature and relative humidity. Weight loss is also associated with the loss of essential damage and darkening of the skin. Therefore it is important to maintain the optimum temperature ranges as much as possible. Surface mold will begin to grow at RH above 90% and sprouting will be stimulated, especially if the temperature is above 16 degrees Celsius and RH is high at the same time at ambient conditions.

Cucumber fruit easily turns yellow and becomes flaccid and shriveled during prolonged storage. Rapid weight declined concomitantly which eventually results in total loss of consumer appeal of the fruits. This has been the root cause of the extremely limited storage life of cucumber fruits for about 2-3 days at normal ambient conditions (Debney et. al., 1980).

Ground storage has no temperature control but they produce rhizomes because of high moisture content. Ginger rhizome is easily damaged when stored at high relative humidity. Usually, small-scale farmers used these methods to enhances sprouts in preparation for the next planting season. Hence, this study tried to evaluate different storage methods to maintain the postharvest quality of ginger rhizomes.

The major problem with ginger is to prolong the shelf life good marketability. The preservation of ginger is imperative especially when it is transport or consumed over a longer period (Camacho and Brescia, 2009). Prolonging the postharvest life of vegetable commodities is one of the primary concerns of farmers and traders. In the countryside, the objective in storage is not to keep the product for a long time but to lessen the perishability so that the usefulness of this product is maximized and a larger profit can be derived, if these crops are to be marketed (Bautista, 1982). Until this treatment is all known and applied, it is unsafe to say that any particular storage method is exactly are correct for all rhizomes or tubers. Soundness and freedom from decay or deterioration are fundamental to profitable marketing, therefore to successful storage and prolong the shelf life of the ginger this was conducted (1) to evaluate the postharvest behavior and quality changes of ginger during storage at different methods, and (2) to determine the shelf life of ginger during storage.

Methodology

Sample Preparation

Ginger rhizomes were harvested at Brgy, Pansagan Baybay City, Leyte when the plant's leaves dried back. They were immediately brought to the Department of Horticulture, VSU, Visca, Baybay, City, Leyte. Rhizomes with the same weight and absence of physical damage were used as samples. Three kilograms of samples in each treatment per replicate were used.

Experimental Design and Treatment

The following treatments were laid out in simple Complete Randomized Design (CRD) with 4 replications per treatment:

A. Ambient Storage

After washing, air drying, and weighing of gingers, they were stored at ambient storage by placing in plastic trays at the postharvest laboratory room. The study was terminated when more than 50% of the treatments showed sprout emergence or when the weight loss reached more than 50%.

B. Evaporative Cooling (EC) storage

After washing, air drying, and weighing of gingers, the ginger rhizomes were stored at the EC located at the back of the DOH postharvest laboratory. For evaporative cooling, water at the top of EC storage was provided to allow continuous dripping into the rice hull of the screen door and surroundings of the EC. These would maintain the moisture of the rice hull so that the ginger rhizome would always be cool during storage.

C. Ground storage

After washing, air drying, and weighing of gingers, ginger rhizomes were stored in the box containing moist soil to simulate ground storage. Ginger rhizome was piled alternately with soil. The last pile was covered with 4 inches thickness of soil.

D. Modified Atmospheric Packaging (MAP) Storage

After washing, air drying, and weighing, gingers were stored and packed in sealed polyethylene bags size of 20×13 with 20 holes diffusion. They were placed in a Styrofoam box and stored in the postharvest laboratory room.

Data gathered

a. **Total Soluble Solids (TSS)-** 100 grams sample rhizomes per treatment per replicate was analyzed for TSS every 7 days. A sufficient amount of juice was extracted and TSS was measured using a handheld refractometer and dilution factor as follows:

b. **Titratable Acidity (TA)-**100 grams sample rhizomes per treatment per replicate were used to analyze TA every 7 days. Five ml of juice was extracted from a 100 gm rhizomes sample and was added with five ml distilled water. Three drops of phenolphthalein indicator were added to it then titrate with 0.1 NaOH until light pink color developed. Percent TA was computed using the following formula:

% TA of Predominant acid= $\frac{V \times N \times M}{W}$ x 100

Where:

V – volume (ml) of NaOH added until light pink color developed

N – normality of NaOH

Me – milliequivalent weight of the predominant acid in ginger which is oxalic acid = 0.045

W– the weight of the rhizome sample in grams

$$\text{Weight} = \frac{weight\ of\ sample}{wt.of\ sample,g \times vol.water\ added,ml} \times vol.of\ aliquot$$

c. **pH-** This was measured at the CAS L' PhilRoot Crop using of electron pH meter.

d. **Dry Matter**-100 grams of ginger rhizomes were finely chip and dried in a solar dryer at the back of PhilRoot Crops. The samples were dried until the constant dry weight was attained and the percent of dry matter was computed using the formula:

$$\text{Percent dry matter} = \frac{weight\ after\ dry}{initial\ weight} \text{ x } 100$$

The percentage moisture content was determined using the formula:

$$\text{Percent moisture content} = \frac{initial\ weight - final\ weight}{initial\ weight} \text{x } 100$$

e. **Decay incidence-** Ginger rhizomes showing decay during storage was counted and expressed as percentage following the formula:

$$\% \text{ Decay} = \frac{number\ of\ ginger\ decay}{total\ number\ of\ ginger} \times 100$$

Likewise, the severity of disease was assessed using the rating or disease severity index as follows:

Disease Severity	Description
1	none
2	Slight: less than 10% of the surface area affected
3	Moderate: 11-25% of surface area affected
4	Severe: 26-50% of the surface area affected
5	Very severe: more than 50% of the surface area Affected

Weight loss/ shriveling- Before storage, the weight of the sample was taken. Weight loss was computed and expressed as a percentage of the initial weight.
Shriveling was assessed using the shriveling index developed by PRCRTC (1982) as shown below.

Index	Description
1	no shrivelling
2	1-19% of the surface area show shrivelling
3	20-49% of the surface area show shrivelng
4	50-71% of the surface area show shrivelling
5	72% and above of the rhizomes show shriveling

VQR-The overall appearance of each sample was assessed for its visual quality or (VQR) using the following rating:

VQR	Description
9	Excellence, no defect
7	Good, defect (yellowing, decay, etc. minor)
5	Fair, defect, moderate
3	Poor, defect serious, limit of marketability
2	Limit of edibility
1	Inedible under usual condition

f. **Shelf life-** The potential shelf life of ginger was determined when the VQR reached 3 or poor, defect serious, and limit of marketability.

g. **Sprouting behavior-** sprout incidence was assessed every sampling period by counting the number of sprouts divided by the total number of samples. Length of sprout per rhizomes was gathered every sampling period using a ruler. The degree of sprouting was assessed using the sprout index (PRCRTC, 1982) below.

1 – no sprout
2– 1-3 sprout/ roots
3 – 4-6 sprout/roots
4 – 7-9 sprout/roots
5 – 10 sprout/roots

h. **Temperature-** the temperature was gathered every week using a thermometer.

i. **RH-** relative humidity was gathered every week using digital relative humidity and thermometer to measure the RH. Monitored dry bulb and wet bulb temperature and calculate the RH using a psychrometric chart using his formula:

$$\% \text{ of RH} = \frac{Actual\ VP,mb}{Saturation\ VP,mb} \times 100$$

j. **Soil-** dry matter content of the soil was gathered at initial, four weeks and final. Garden soil was used for ground/pit box storage methods which were taken near the Tissue Laboratory of VSU.

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Results and Discussion

TA/TSS

Titrable acidity is a measure of the amount of acid present in a solution. The initial TA was 0.19 before storage and increased during storage (Table 1.). No significant differences were observed among storage methods except on the ninth week of storage. Those rhizomes stored at EC exhibited the lowest TA value. The occurrence of decay might be the reason for the low TA values of the EC stored gingers. Thereafter, the TA values were already similar among storage methods. The total soluble solids (TSS) on the other hand, is the sum of the soluble solids. It is also an approximate measure of the sugar content of a commodity. TSS was measured 2.4 Brix before storage. Like TA no significant differences were observed among storage methods except on the fifth week of storage. The TSS ranged from 2.1˚ to 3.9˚ Brix (Table 2). Ambient-stored ginger had significantly higher TSS than the other stored gingers on the fifth week of storage. Beyond this period, TSS values were already similar among storage methods, though those ginger stored at ambient had numerically higher values than those ginger stored from other methods.

Table 1. Titratable acidity of ginger rhizomes during storage at different storage methods.

Storage Method	STORAGE PERIOD (weeks)						
	1	3	5	7	9	11	13
Ambient Storage	0.33	0.42	0.69	0.54	0.64a	0.64	0.64
Evaporative Cooling Storage	0.54	0.26	0.55	0.46	0.24b	0.59	0.59
Ground/Box Storage	0.62	0.33	0.55	0.52	0.52a	0.52	0.52
MAP Storage	0.34	0.49	0.43	0.31	0.52a	0.71	0.59
CV(%)	54.64	31.02	31.08	31.73	24.23	55.78	27.82
Pvalue	0.34	0.07	0.25	0.15	0	0.89	0.8

*Means followed by the same 'letter (s) within storage terminate are not significantly different from each other at 0.05 LSD

Table 2. The total soluble solid of ginger rhizomes during storage at different storage methods.

Storage Method	STORAGE PERIOD (weeks)						
	1	3	5	7	9	11	13
Ambient Storage	2.8	3.45	3.60a	3.9	3.6	3.6	3.6
Evaporative Cooling Storage	2.7	2.9	2.20b	3.4	2.1	2.8	3.4
Ground/Box Storage	2.4	3.3	1.90b	2.4	2.4	2.4	2.4
MAP Storage	2.5	2.9	2.50b	3.1	2.2	3.5	2.8
CV(%)	18.58	21.75	21.48	30.3	32.88	32.9	38.79
Pvalue	0.64	0.58	0	0.23	0.09	0.32	0.49

*Means followed by the same 'letter (s) within storage terminate are not significantly different from each other at 0.05 LSD

PH

The pH of the rhizomes ginger stored at different storage methods is shown in (Figure 1.). Before storage, the pH measured 6.4 which is slightly acidic. Among the five storage methods, the pH of ginger rhizomes stored in-ground storage showed the lowest pH after storage. The resumption of growth during ground storage was probably the reason for the slight decrease in pH. Normally, growing tissues have a pH value of 5.5 to 5.7 (Taiz and Zeiger, 991).

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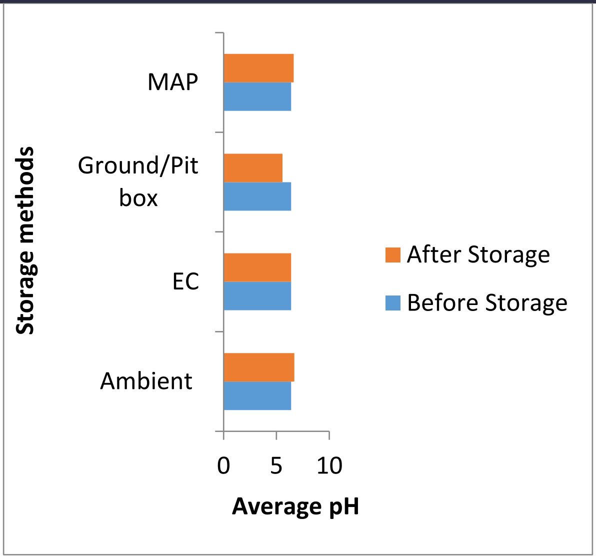

Figure1. the pH of ginger rhizomes during storage methods.

Dry Matter Content

Table 3 and Appendix Table 4. show the dry matter and ANOVA of ginger rhizomes stored at different storage methods, respectively. Ginger has low dry matter content which ranged from 4.45% to 7.35% after storage. Dry matter content in ginger stored in evaporative cooling storage (EC) is significantly higher than the other storage methods. Correspondingly, it incurred the lowest moisture content. The low moisture loss of EC-stored ginger contributed to the high moisture content. On the other hand, the resumption of growth and the gain in weight in ground-stored ginger were possibly the reasons for the high moisture content after storage.

Table 3. Dry matter and moisture contents of ginger rhizomes were stored at different methods.

Storage Method	Dry matter (%)		Moisture content (%)	
	Before Storage	After Storage	Before Storage	After Storage
Ambient Storage	4.8	4.45b	95.2	95.90a
Evaporative Cooling Storage	4.8	7.35a	95.2	93.15b
Ground/box Storage	4.8	5.28b	95.2	95.38a
MAP Storage	4.8	6.25ab	95.2	94.00ab
CV(%)		20.18		1.38
P-value		0.02		0.04

*Means followed by the same 'letter (s) within storage terminate are not significantly different from each other at 0.05 LSD.

Decay

Table 4 shows the decay incidence of ginger stored at different storage methods. Decay started to manifest on the 3rd week of storage and progressively increased with time of storage. Ginger rhizome stored at EC had consistently lower decay incidence especially on the later part of storage compared to other storage methods. During the 7th week of storage ambient- stored ginger exhibited the highest decay incidence but not significantly different from these ground- stored ginger. EC storage provided low temperature and high relative humidity which are important in ginger storage. There was a decrease in the decay incidence of ginger after the 9th week of storage because samples with severe infection were already removed from the storage chamber to minimize contamination of the remaining samples.

Table 4. Disease incidence of ginger rhizomes during storage at different storage methods.

Storage Method	STORAGE PERIOD (weeks)						
	1	3	5	7	9	11	13
Ambient Storage	0	13.61	40.05b	82.71a	50.86	50.86	50.86
Evaporative Cooling Storage	0	9.71	21.73c	54.11c	56.91	53.08	40.59
Ground/Box Storage	0	8.58	67.51a	71.66ab	71.66	71.66	71.66
MAP Storage	0	13.77	35.48bc	58.00bc	62.00	52.05	52.05
CV(%)		81.92	26.52	16.54	29.12	30	30.59
P-value		0.33	12.35	5.66	1	1.34	2.49

*Means followed by the same 'letter (s) within storage terminate are not significantly different from each other at 0.05 LSD.

On the other hand, the severity of decay was only slight, less than 2.0 which suggested less than 10% of surface area were infected

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during the first 5 weeks of storage. Those ginger stored at ambient had the highest severity index. The high temperature during ambient storage was probably the reason for high disease severity. Thereafter, the severity ratings were already similar in all storage methods.

Table 5. Disease severity of ginger rhizomes during storage at different storage methods.

Storage Method	STORAGE PERIOD (weeks)						
	1	3	5	7	9	11	13
Ambient Storage	1	1.16	1.51b	2.67a	1.84	1.84	1.84
Evaporative Cooling Storage	1	1.18	1.24b	1.85b	1.48	1.84	1.54
Ground/Box Storage	1	1.12	1.82a	1.92b	1.92	1.92	1.92
MAP Storage	1	1.22	1.50b	1.92b	1.53	1.71	2.24
CV(%)		16.99	12.78	16.24	30.73	30.95	33.9
P-value		0.18	6	5.2	0.73	0.1	0.82

*Means followed by the same 'letter (s) within storage terminate are not significantly different from each other at 0.05 LSD. Disease severity index used: 1- none, 2- slight: less than 10% of the surface area affected, 3- moderate: 11-25% of the surface affected, 4- severe: 26-50% of the surface area affected, 5- very severe: more than 50% of the surface area affected

Cumulative weight gain/weight loss

Shown in Figure 2 is the gain/loss of weight of ginger rhizomes during storage. Ground/box storage favored an increase in the weight of the rhizomes because of the resumptions of their growth. Shoot emergence was observed in the box-stored ginger. There was a decrease in weight in those rhizomes stored at ambient, modified atmosphere, and evaporative cooling storage methods. The prevailing relative humidity inside these methods (Table 12.) was relatively low, hence moisture loss is inevitable. Ambient-stored ginger incurred the highest weight loss during storage.

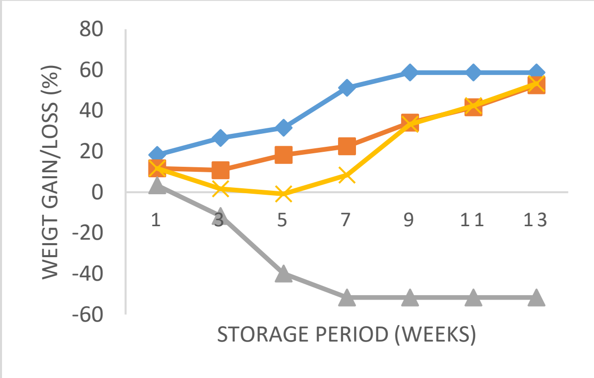

Figure 4. Cumulative weight loss/gain of ginger rhizomes during storage.

Shriveling

Ginger rhizomes started to show shriveling on the 3rd week of storage (Table 5.) Ambient stored ginger showed the highest shriveling during storage which was significantly high on the 5th and 7th week of storage. High temperature favored high transpiration., thereby results in high weight loss that consequently led to increased shriveling. After 9 to 13 weeks, the shriveling of the ginger rhizomes was already similar among storage methods. There was a decrease in the shriveling index after 9 to 13 weeks of storage because samples with decay were already terminated on the 7th week of storage.

Table 6. Shriveling of ginger rhizomes during storage at different storage methods.

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Storage Method	STORAGE PERIOD (weeks)						
	1	3	5	7	9	11	13
Ambient Storage	1	1.13	2.41a	3.02a	1.92	1.92	1.92
Evaporative Cooling Storage	1	1.11	1.26b	1.55b	1.37	1.92	1.11
Ground/BoxStorage	1	1.03	1.19b	1.21b	1.21	1.21	1.21
MAP Storage	1	1.10	1.14b	1.54b	1.46	1.63	1.63
CV(%)		6.95	13.56	13.32	35.84	37.55	38.54
P-value		1.29	35.69	43.92	1.29	1.24	1.75

*Means followed by the same 'letter (s) within storage terminated are not significantly different from each other at 0.05 LSD. Shriveling index used: 1)- no shriveling, 2) 1-19%- surface area show shriveling, 3) 20-49%- surface area show shriveling, 4) 550-79%- surface area show shriveling, 5) 72% above of the rhizomes show shriveling.

VQR

The visual quality of ginger rhizome during storage declined which may be attributed to both physical and pathological (Table 7). Ambient-stored ginger had the lowest visual quality on the 3rd week of storage while those ginger stored at EC, MAP, and box storage had high VQR. The low RH at ambient condition enhance faster VQR reduction. The occurrence of dry rot was responsible for the drastic VQR reduction at ambient conditions. On the other hand, ginger rhizomes stored at evaporative cooling, modified atmosphere (MAP), and ground storage method were infected with soft rot. Ground- stored ginger had consistently high VQR because of their growth resumption. The VQR of stored gingers was still acceptable after 7 weeks of storage in all storage methods. Beyond this period, the VQR drastically decline because of decay.

Table 7. Visual Quality Rating (VQR) of ginger rhizomes during storage at different storage methods.

Storage Method	STORAGE PERIOD (weeks)						
		3	5	7	9	11	13
Ambient Storage	9	7.14b	6.15	3.04c	1.76c	1.76b	1.76b
Evaporative Cooling Storage	9	7.97a	6.45	5.14b	3.08b	2.15b	1.38b
Ground/Box Storage	9	8.71a	7.15	6.75a	6.75a	6.75a	6.75a
MAP Storage	9	8.00a	7.07	4.71b	2.90bc	2.02b	1.40b
CV(%)		6.47	12.09	9.14	21.92	23.39	25.35
P-value		0.01	0.28	0	0	0	0

*Means followed by the same 'letter (s) within storage terminated are not significantly different from each other at 0.05 LSD. VQR used: 9- excellent no defect, 7- good and defect, 5- fair, defect and moderate, 3- poor, defect serious and limit the marketability, 2- limit of edibility, 1- inedible under usual condition.

Shelf life

Ambient-stored ginger rhizomes had the lowest potential shelf life because of excessive weight loss and reduction of visual quality. EC and MAP had significantly lengthened the shelf life of the stored ginger rhizomes. The favorable temperature and relative humidity minimized the drastic reduction of the VQR. On the other hand, ground- stored had shorter shelf life because of the growth resumption thereby affecting the overall quality especially of the presence of more sprouts (Table 11).

Table 8. Potential (days) shelf life of ginger rhizomes during storage.

Storage Method	Shelf life (days)
Ambient Storage	38.12b
Evaporative Cooling Storage	46.03a
Ground/Pitbox Storage	41.40b
MAP Storage	46.61a
CV(%)	8.83
P-value	4.48

*Means followed by the same 'letter (s) within storage terminated are not significantly

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different from each other at 0.05 LSD. VQR used: 5 Fair, defect, moderate.

Sprouting Incidence

Ginger rhizomes started to sprout even after one week of storage MAP- stored ginger had significantly the highest sprout incidence during the first 7 weeks of storage (Table 9). Ground box storage favored high sprout incidence during the later part of storage because of high moisture of the soil and nutrient of garden soil aside from the dark condition. Rhizomes preferred dark conditions for sprouting. Under field conditions, ginger rhizomes are placed underground to initiate sprouting for the next planting season (personal communication).

Table 9. Sprout incidence of ginger rhizomes at different storage methods.

Storage Method	STORAGE PERIOD (weeks)						
	1	3	5	7	9	11	13
Ambient Storage	1.48b	2.29b	2.48c	2.29c	1.38c	1.38c	1.38b
Evaporative Cooling Storage	1.69b	2.51b	2.72bc	2.57bc	2.13bc	1.81bc	1.45b
Ground/Box Storage	1.49b	2.56b	3.12ab	3.25ab	3.25a	3.25a	3.25a
MAP Storage	2.65a	3.49a	3.59a	3.42a	2.66ab	2.27b	1.77b
CV(%)	14.09	12.41	13.06	17.72	25.75	24.06	24.92
Pvalue	0	0	0.01	0.02	0.01	0	0

*Means followed by the same 'letter (s) within storage terminated are not significantly different from each other at 0.05 LSD. Sprout index used: 1- no sprout, 2) 1-3 sprouts, 3) 4-6 sprouts, 4) 7-9 sprouts, 5) 10 and above sprouts.

Length of Sprout

The length of the sprout of ginger rhizomes during storage is shown in Table 10. Ground-stored ginger had significantly longer sprout than those ginger stored in other storage methods. Aside from the presence of the nutrient and moist condition, the dark condition inside the ground storage enhances faster sprout elongation. Ambient-stored ginger had the shortest sprout during storage because of the high temperature that increases transpiration and hence, moisture loss.

Table 10. Height (cm) of the sprout of ginger rhizomes at different storage methods.

Storage Method	STORAGE PERIOD (weeks)					
	3	5	7	9	11	13
Ambient Storage	2.33c	3.69b	3.95b	2.44b	2.44b	2.44b
Evaporative Cooling Storage	3.38b	5.31b	7.53b	6.32b	6.32b	5.23b
Ground/Box Storage	6.38a	12.13a	16.76a	16.76a	16.76a	16.76a
MAP Storage	3.49b	5.29b	5.88b	3.79b	3.02b	3.02b
CV(%)	17.6	22.21	52.15	60.73	61.94	64.82
Pvalue	0	0	0.01	0	0	0

*Means followed by the same 'letter (s) within storage terminated are not significantly different from each other at 0.05 LSD.

Number of the Sprout

Several sprouts of stored ginger are shown in Table 11. MAP-stored ginger had more sprout which was significantly higher compared to ginger stored in other methods of storage. However, they were not significantly different from those ginger stored in the box after 5 to 13 weeks of storage. Ambient- stored ginger had the least number of sprouts because of high transpiration due to low relative humidity. Excessive weight loss minimized the emergence of new sprouts.

Table 11. A total number of sprouts of ginger rhizomes during storage methods.

Storage Method	STORAGE PERIOD (weeks)						
	1	3	5	7	9	11	13
Ambient Storage	0.75b	2.48b	3.15c	3.28c	1.92b	1.92c	1.92b
Evaporative Cooling Storage	1.16b	3.56b	4.57bc	4.68bc	4.12ab	3.56bc	2.81b
Ground/Box Storage	0.78b	3.70b	5.61ab	5.96ab	5.96a	5.96a	5.96a
MAP Storage	4.19a	7.25a	7.76a	7.42a	5.84a	5.50ab	4.62a
CV(%)	52.86	29.25	27.56	29.26	32.16	30.69	29.56
Pvalue	0	0	0.01	0.02	0.01	0	0

*Means followed by the same 'letter (s) within storage terminated are not significantly different from each other at 0.05 LSD. VQR used:

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Temperature

The temperature varied among storage conditions where MAP exhibited the highest temperature after 3 and 9 to 13 weeks of storage of ginger rhizomes (Table12). The storage was affected by the temperature of the atmosphere inside the polyethylene bag with a styrofoam box. Evaporative cooling storage had consistently low temperature because of the continuous drifting of water outside of the storage chamber. On the other hand, box storage had a consistently high temperature because of exposure to sunlight.

Table 12. Temperature (℃)of ginger rhizomes during different storage methods.

Storage Method	STORAGE PERIOD (weeks)						
	1	3	5	7	9	11	13
Ambient Storage	28.00	28.00b	30.00b	28.00b	27.25b	27.25b	27.25c
Evaporative Cooling Storage	27.00	28.00c	27.00c	27.00b	30	28.50ab	28.00bc
Ground/Box Storage	27.50	28.50ab	31.25a	29.75a	29.75a	29.75a	29.75a
MAP Storage	28.00	29.25a	30.00b	28.25b	29.25a	29.75a	29.00ab
CV(%)	2.76	2	2.13	3.15	3.48	3.36	3.72
Pvalue	0.25	0	0	0.01	0.01	0.01	0.033

*Means followed by the same 'letter (s) within storage terminated are not significantly different from each other at 0.05 LSD.

RH

The relative humidity inside the storage chamber is shown in Table 13. Evaporative cooling storage consistently had high RH inside the chamber. Continuous drifting of water within the rice hull cover maintained the high relative humidity. Ambient storage had the lowest RH during storage. Based on this result those ginger stored at ambient had high weight loss and hence, more shriveling was incurred.

Table 13. Relative humidity of ginger rhizomes during storage at different storage methods.

Storage Method	STORAGE PERIOD						
	1	3	5	7	9	11	13
Ambient Storage	56.00c	56.00c	52.00c	31.00b	36.00c	36.00b	36.00b
Evaporative Cooling Storage	77.00b	82.00a	88.00a	78.00a	74.00b	81.00a	84.75a
Ground/box Storage	83.25a	84.50a	81.75b	83.25a	83.25a	83.25a	83.25a
MAP Storage	78.75b	76.50b	81.25b	80.25a	75.50ab	77.75a	83.50a
CV(%)	3.49	3.7	5.13	5.55	7.9	6.77	5.21
Pvalue	0	0	0	0	0	0	0

*Means followed by the same 'letter (s) within storage terminated are not significantly different from each other at 0.05 LSD.

Moisture Content of Soil

Garden soil near the Tissue Laboratory of the Department of Horticulture was used for ground storage. The soil moisture was maintained between 20% to 22% during the storage of ginger rhizomes. There was a sudden increase in the soil moisture on the 7th week of storage because of the continuous rain attributed to typhoons during that period.

Table 14. The soil moisture content of the ground/box storage

Replication	initial	Moisture content			
		week 3	week 5	week 7	mean
1	15	25.8	22.8	26	19.12
2	15	24.2	20.4	26	19.52
3	15	22	21.8	26	20.56
4	15	20.8	24.4	26	22.04
mean	15	23.2	22.35	26	

Conclusions

Based on the results, the following can be drawn:

1. Ground storage was effective in slowing VQR reduction because of the growth resumption.

EC and MAP provided high relative humidity conducive for ginger storage.

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