# EFFECT OF MODIFIED ATMOSPHERE ON STORAGE LIFE OF LIME AT LOW TEMPERATURE

By

**T G WICKREMA**

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Faculty of Applied Sciences,
Sabaragamuwa University of Sri Lanka,
Buttala, Sri Lanka.

# DECLARATION

The work is described in this thesis was carried out by me at the Faculty of Applied Sciences under the supervision of Dr.(Mr.) K.H.Sarananda and Mr.Jagath Wansapala. A report on this has not been submitted to any other University for another degree.

W. R.
..........................................
T G Wickrema
Date : 14/12/00

Certified by

Dr.(Mr.) K H Sarananda,
External Supervisor,
Research Officer,
Food Research Unit,
Department of Agriculture,
Gannoruwa,Peradeniya.

..........................................
Date : 14/12/00

Mr Jagath Wansapala
Internal Supervisor,
Course co-ordinator,
Dept. of Food Sc. And Technology,
Faculty of Applied Sciences,
Sabaragamuwa University of Sri Lanka,
Buttala,Sri Lanka.

..........................................
Date : 27/12/2000

AFFECTIONATELY DEDICATED
TO
MY EVERLOVING PARENTS
AND
TEACHERS

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**Abstract**

Experiment was carried out to increase the storage life of lime using modified atmosphere at 8-10$^0$ C. Fruits were packed in low density polyethylene bags with 200 and 300 gauge. At each gauge half of the bags were vacuum packed and sealed. Control fruits were kept in perforated bags, Percentage weight loss, disease incidence, and visual quality rating were recorded at two weeks interval.

Control fruits ripened within 2 weeks of storage having a higher percentage of weight loss. All MA stored fruits remained up to 8 weeks of storage at 8-10$^0$ C. However, high disease incidence and possibly $CO_2$ injuries developed in 300 gauge bags and vacuum packed bags. The best method of packaging was 200 gauge sealed low density polyethylene bags. Fruits stored in 200 gauge bags were in very good quality after 8 weeks of storage.

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# CHAPTER 1

## INTRODUCTION

Major portion of the lime is cultivated in the Uva province of Sri Lanka especially in Bibile and Moneragala. In addition to Uva province, lime is cultivated in Kurunagala, Vavuniya and Puttlam. Lime cultivation is highly seasonal. At peak production time, a large quantity of harvested lime is wasted due to post harvest losses. In the production season a higher volume of lime come to the market and as a result of over supply the price of lime goes down even up to one rupee per I kg.

As lime is a perishable fruit, the post harvest loss is very high. Perishability of lime is accelerated by improper handling practices, damages during transport and storage.

The price of lime goes down during the season due to poor distribution system to other areas and the unavailability of storage facilities. Very high price drop during season affect the economy of lime grower and less care is given for the produce. One way of solving this problem is scattered production of lime to avoid gluts at the market. It has been reported that scattered production of lime can easily be done by irrigation of plant before rains commence. Although this technique is sound unavailability of water during flower induction period causes practical limitations. The other possibility of preventing excessive supply of lime to the market is storage of lime like other vegetables. Lime may be stored at low temperature so that stored lime can be put to the market when production is terminated.

## OBJECTIVES

In the present study, experiments were carried out with following objectives.

- Effect of low temperature on extending storage life of lime.
- Effect of modified atmosphere on extending storage life of lime.

## CHAPTER 2

## 2.0 LITERATURE REVIEW

Lime is an evergreen plant, which has a comparatively long life (Mankad, 1994). The lime probably originated in India and spread to Middle East and other tropical and sub tropical countries (Salunkhe and Desai, 1984). The crop grows well in frost from sub tropical to semi tropical climate. Best growth of lime occurs within $29^0$C - $35^0$C. And higher mean annual temperature results in early maturing and bigger sized fruits. An annual rainfall of 700 mm is sufficient if it is well distributed. The ideal soil pH is 5.5 - 7.5 and it does not grow in saline and alkaline soil. Even though there are seasonal limitations, the consumption of fresh fruit is limited because of perishable nature and high post harvest losses (Mankad, 1994).

### 2.1 Botany of Crop

The genus *Citrus* is consists of two sub genera; *Papeda* and *Eucitrus* Fruits of *Papeda* are inedible because of numerous droplets of acrid oil in the juice sacks. *Eucitrus* consists of ten species; eight of which are cultivated. The botanical and English names of these are as follows (Salunkhe AND Desai, 1984).

| | |
|---|---|
| *Citrus sinensis* | -Sweet orange |
| *Citrus aurantium* | -Sour orange |
| *Citrus reticulata* | -Mandarin |
| *Citrus paraidisi* | -Crop fruit |
| *Citrus grandis* | -Shaddock |
| *Citrus limon* | -Lemon |
| *Citrus medica* | -Citron |
| *Citrus aurantifilic* | -Lime |

In Sri Lanka, an acid lime cultivar is known as <u>Moneragala</u> lime and another lime, known as <u>Thimbutane</u> lime (a small leaf type) are promising cultivars of acid lime (Ghosh and Singh, 1994)

## 2.2 Nutritional significance of lime

Lime is a rich source of Calcium.

| Composition | Values |
|---|---|
| Moisture | 84.6 % |
| Protein | 1.5 % |
| Fat | 1.0 % |
| Minerals | 0.7 % |
| Fibre | 1.3 % |
| Carbohydrate | 10.9 % |
| Energy | 59 (kcal) |
| Calcium | 90 mg |
| Phosphorus | 20 mg |
| Iron | 0.3 mg |
| Carotene | 15 µg |
| Thiamin | 0.02mg |
| Riboflavin | 0.03 mg |
| Niacin | 0.1 mg |
| Vitamin C | 63 mg |

(Source Sanjeer,1994)

## 2.3 Production of lime

In 1993, the annual world production of lemon and lime was estimated to be 7708 thousand tons ). Lime plant which belongs to a good variety (seven years old) has an annual yield of 2000-6000 fruits, weighing 75 -100kg under favorable conditions (Mankad, 1994). In Sri Lanka, area under the lime is about 2562 ha during 1982 -1983, About 29,300 MT of lime were produced in Sri Lanka during 1981 and 1997 (Ghosh and Singh, 1994).

## 2.4 Post harvest losses

In Sri Lanka, lime season lies between late May to early August. Most of lime produced comes to Market in this period. So the price of lime goes down to about Rs.1 - Rs.5 per kg. According to Agricultural Research Policy Report, 1998, average post harvest loss of lime by producer is 2%, Collector 5% whole sales 8%, and retailer 5%. Then total loss of lime is

20%. Poor handling practices, poor transport facilities, lack of storage facilities and no proper technology application are the main reasons for the very high loss.

## 2.5 Post harvest diseases

### 2.5.1 Fungal diseases

1. Altarnaria rot

Causal fungus is *Alternaria citri when* lemons are stored at 13$^0$C - 15$^0$C.

Symptoms are diseased fruit in the orchard colour prematurely and may develop a light brown to blackish discolouration of the ring at or near the stylar end (Whitesid *et.al.*, 1993).

2. Blue mold

Causal fungus is *Penicillium italicum* blue mold occur in all citrus producing regions of the world. Light green mold, although it is generally less prevalent than green mold. All types of citrus fruit are susceptible to blue mold. Like green mold it develops most rapidly at about 24$^0$C however, blue mold grows better than green mold below 10$^0$C and may predominate over green mold in fruit stored at such temperature (Whiteside, *et al.*, 1993).

2. Green mold

Green mold is the most common and serious post harvest disease of citrus fruit. Initial symptoms of green mold are similar to those of sour rot and blue mold.

The causal fungus of green mold is *Penicillium degitatum.* Develops most rapidly at in the temperatures near 24$^0$C and much more slowly above 30$^0$C and below 10$^0$C. The rot is almost completely inhibited at 1$^0$C (Whiteside, *et al.*, 1993).

## 2.6 Physiological disorders of lime

**1. Oleocellosis**

Oleocellosis is also known as oil spoting is caused by the phytotoxin action of peel oil relates on the surface of the ring as a result of abrasion, rough handling, thorn punctures or other injuries. The rind of lime is especially delicate and prone to oleocellosis in foggy wet condition exacerbates the disorders by making the rind mode turgid and subject to the rupturing of oil glands, and contact between wet fruit and sand during harvest is especially hazardous. Peel oil can also be released when turgid fruit is exposed suddenly to low temperatures.

Lime is susceptible to oleocellosis that pressure testers are used to measure the pressure at which oil glands rupture to determine when the pressure is high enough to permit safe harvesting. Lime are commonly left in the field overnight in pallet box to allow the turger pressure to decline. The lower turger pressure permits safer transport to the packing house (Whiteside *et al.*, 1993).

**2. Chilling injury**

Some citrus fruits develop a peel injury known as chilling injury when stored at temperatures below $10^0$C. This should not be confused with freeze injury, which is caused by temperatures below $0^0$C. Chilling injury occurs most frequently on lime and appears as sunken pits on the peel surface.

Chilling injury can be avoided by strains and transporting fruit at higher temperature. But, this increase the risk of decay, partial control can be achieved by applying wax or certain film wraps to decrease moisture loss from the rind or by treat fruit with fungicides, however, lime exhibit more chilling injury when waxed. The risk of injury is reduced by lowering the storage temperature slowly and by raising it intermittently during cool storage (Whiteside, *et al.*, 1993).

3. Creasing

Creasing consists of grooves or furrows in an irregular pattern in the rind. This disorder occurs on several types of citrus, most commonly on very mature fruit. Thin-skinned fruit are especially susceptible to creasing as well as subsequent splitting. Creasing is though to be related to a complex of pre-harvest factors, including potassium nutrition but the causes are rot fully understood. Pre harvested sprays of Gibberellic Acid have been reported to reduce creasing in Australia and South Africa (Whiteside *et al.*, 1993).

## 2.7.Methods to reduce post-harvest loss

### 2.7.1 Lime processing

Processing of lime is one of the major ways for preserving. Fruits which are not suitable to fresh fruit market such as under sized, off- graded, or with skin blemishes, and chilling can be processed.

There are commercially applicable ways to extend post harvest life of perishables by slowing down the respiration rate and physiological changes accompanying with it.

### 2.7.2 Fruit coating techniques

This technique is used to prolong shelf life of lime. Use polythene liners for conditioning TAHITI Limes to reduce chilling injury (Donald.and Feeder, 1983). Under evaporative cooling storage condition, Fungicide Bavistin at 1000 ppm were dip treated Citrus fruit (orange). (Habibunnisa and Narasngham, 1987). Waxing minimizes weight loss and extends storage life by inhibiting moisture loss from the rind of citrus fruits without adversely interfering with respiratory gas exchanges (Aworh, *et.al*, 1991).

The coatings used for Citrus are usually called "waxes" although modern products commonly available contain little it any wax of any kind. There are several types of waxes such as solvent wax, water wax. (Hall, 1981). The specific treatment varied between tests but included temperature of 15, 18, 21, 27$^0$C etthopan at 0, 250,300,500,700,1000,2000 ppm solvent wax at 0 normal and hard strength, TBZ fungicide at 0, 1000 ppm and ethylene at 0, 10 ppm (Jahni, 1976).

### 2.7.3 Storage improvements

**Controlled Atmosphere storage (CAS)**

Controlled Atmosphere Storage (CAS) refers to the storage of food in an atmosphere that is different from the normal composition of air. In CAS the atmosphere components are precisely adjusted to specific concentration. CAS is used for ware house storage or to transport bulk of perishable foods. Optimal CAS conditions vary on each commodity. Specific levels of gasses are maintained and regulated by external sources. Optimal gas compositions, relative humidity and temperature of the atmosphere differ from different fruits. Commercial gas generators are used to replace air with chosen gas atmospheres.

**Table 2.1:Controlled and Modified Atmosphere conditions for storage of lime**

| Fruit | Application | Temp °c | Atmosphere %$O_2$ %$CO_2$ | Benifits |
|---|---|---|---|---|
| Lime | Storage | 10 | 5 7 | Moderate |

(Source: Wardowski 1986)

**2.7.3.1 Hypobaric storage**

It is controlled atmosphere storage. But, storage area is maintained under reduced pressure and high humidity. It can be used in warehouses and enclosed truck bodies.

**2.7.3.2 Refrigerator storage**

Refrigeration or cold storage is referred to storage at temperatures above freezing point from about 16$^0$C - 20$^0$C. It generally preserves perishable foods. Low temperature reduces rate of metabolic activities of perishables. It also reduces microorganism activities.

**2.7.3.3 Modified Atmosphere Packaging (MAP)**

Modified atmosphere is created when fruits sealed in packaging films with intermediately to gases. When fruit respires, in package gaseous composition is altered (Day, 1995). Therefore, metabolic activities accompanied with respiration rate of fruits are decreased. It extends post harvest life of fruits. MAP extends post-harvest life of fruits under ambient conditions without affecting quality of the fruit, instead of existing high cost commercial methods.

**2.7.3.3.1.Principles of MAP**

Film packaging, which made of packaging materials, with correct intermediate permeability to gases, involves atmospheric modification surrounding the product by altering of in-package gaseous composition.

Respiration is the process, which consumes oxygen and emits carbon dioxide transmission through the package equal to rate of products, beneficial EMA (Equilibrium Modified

Atmosphere) is established with its specific optimal atmosphere and relative humidity within the package. Exact EMA can also be influenced by stage of maturity of commodity, storage temperature and ratio between film surface area and fruit weight of the MAP system. As generalization EMA of MAP system contains 2 -5 % of oxygen and 3 - 8% of Carbon dioxide levels which extends shelf life and do not cause of physiological injuries (Day, 1995). In contrast to that, alternative way of MAP involves replacing the package atmosphere with desired gaseous mixture or use of carbon dioxide, oxygen or ethylene scavengers/emitters, which are capable of establishing rapid EMA within the package.

In context of MAP which involves altered composition of atmosphere with respect to proportion of oxygen and / or Carbon dioxide levels collectively retards rate of respiration, bio- chemical changes associate with respiratory metabolism including ethylene climacteric rise, autocatalytic production of ethylene and enzymatic regulations. Therefore, it retards ripening, senescence, deterioration process and other physiological changes accompanying with rate of respiration. It collectively extends post-harvest life.

MAP systems are designed to achieve a desirable equilibrium modified atmosphere (EMA) with a particular commodity by optimizing the package design (Day,1995).

**2.7.3.3.2.Methods of creating MAP**

MAP systems can be created either passively by commodity or intentionally by active packaging.

**2.7.3.3.3.Passive MAP**

MA storage can be created passively within a hermetically sealed packaged as a consequence of a commodity respiration. If respiration Characteristics are properly matched to film permeability created desirable EMA, when rates of oxygen and Carbon Dioxide transmission through the package equal to rate of respiration of the product.

**2.7.3.3.4.Active MAP**

It is the establishment and adjustment of the atmosphere within a produce package. Beneficial EMA creates more quickly by replacing the package atmosphere with a desired mixture of oxygen and carbon dioxide.

Use of scavengers of oxygen, carbon dioxide, or ethylene leads to rapid EMA within the packaging. Ethylene scavengers help to delay the climacteric rise and reduce the respiration rate of produce. Carbon dioxide scavengers prevent accumulation of carbon dioxide up to injury level.

**2.7.3.3.5.Metabolic effect of MAP**

Early investigators of MA storage recognized that this new type of storage causes changes in the basic metabolic processes of the stored fruits (Salunkhe *et al* , 1991).

**2.7.3.4.Retarded respiration**

Respiration is one of the metabolic processes influenced by MA storage. The MA storage can influence at three levels.

1.Aerobic respiration

2.Anaerobic respiration

3.A combination of these two

Aerobic respiration occurs when the $O_2$ supply is normal and results in liberation of $CO_2$ and water. Anaerobic respiration, taking place in atmospheres completely devoid of $O_2$, produces $CO_2$ and ethyl alcohol by fermentation. When $O_2$ is low, both processes function to a degree that depends on the relative concentration of $O_2$.

This evidence by the development of failure to soften properly, off-flavours, or even a complete breakdown of tissue before normal ripening process are completed. The respiration rate of fruits removed from conventionally refrigerated storage increase for about eight days. The fruits from MA storage increase in respiration soon after removal from treatment. However this increase is generally note as accentuated (Salunkhe. *et.al.*, 1991).

**2.7.3.5.Pectin changes**

The $CO_2$ storage may have an effect on protopectin hydrolysis. The soluble pectin content is much higher where higher temperatures or no $CO_2$ are involved. The rate of pectin degradation is affected by both time and condition (Salunkhe *et.al.*, 1991).

### 2.7.3.6.Adverse and Toxic effect of MA/CA

Fruit can be damaged when a large amount of $CO_2$ is present in the storage room. Controlled atmosphere storage has great promise, but also can have adverse effects on fruits. The biochemical constituents of fruit show changes in an unusual manner during CA storage. Injury to fruit tissue can occur from decay and abnormality of metabolism induced by high $CO_2$ and low $O_2$ concentrations. Some of these disorders are in the form of browning of the fleshy mesocarp tissue breakdown, and the accumulation of certain organic acids, succinic acid at concentrations less than 0.001M is toxic to fruit. If there is a complete lack of $O_2$ for several days, the fruit will suffocate and become badly off flavored. Increased $CO_2$ bicarbonate mixtures markedly affect the rate of several enzyme reactions.

Tissue browning is another disorders of fruits. One of the main courses of this discoloration is biochemical change in tannins. During storage and senescence, these compounds are hydrolyzed; toxic product could be accumulated in the tissue, possibly resulting in loss of cells and saving as substrates for enzymatic browning reactions (Salunkhe. *et.al*, 1991).

### 2.7.3.7.Off-flavour production at high $CO_2$

At high $CO_2$ concentrations (15% or more), off-flavour is usually produced in lime and other commodities. In some cases, off-flavour may be due to an accumulation of ethanol. Concomitant with the development undesirable flavour, off-colour may also observed (Salunkhe .*et.al*, 1991).

## CHAPTER 3

## 3.0 Materials and Method

### 3.1 Materials

1. Lime

   Fully mature green Limes were harvested from a farmer's field in Monaragala District and transported to the laboratory in Food Research Unit at Peradeniya.
2. Polyethylene

   200 and 300 gauge low density polyethylene used for packaging.
3. Refrigerator / Cold room.
4. Electric Polyethylene sealer.

   Used to seal the polyethylene bags.
5. Rubber bands.

   Used for packaging.
6. Knife

   Used to cut the polyethylene bags.
7. Electric balance

   Used to weigh the samples.

## 3.2 Method

### 3.2.1 Sealed Packaging.

The fresh lime fruits were weighed and packed in 200 gauge polyethylene bags and sealed with the air using polyethylene sealer and stored in a cold room maintained at $8^0$C-$10^0$C. The following parameters were recorded 2 weeks interval for up to 8 weeks.

#### 3.2.1.1.Peel Colour

Peel colour of lime was recorded by using peel colour index as follows

1. Green colour,
2. Colour Break,
3. More Green than Yellow,
4. More Yellow than Green,
5. Full Yellow

#### 3.2.1.2.Diseases

Diseases of lime were recorded by using a disease index as follows. Individual lime was assessed for diseases

0-No diseases appear,
1-Slightly disease appear less than 10%,
2-Diseases are moderate about 11% -20,
3-Diseases are high about 21% - 30%
4-Diseases are more than 30%.

#### 3.2.1.3.Visual Quality Rating

Fruit quality was measured based on external appearance of fruits, using following index. Individual fruit was assessed in each sample.

1-Not edible,
3-High defects can not be sold,
5-High defect but can be sold,
7-Quality is defect moderate
9-Quality excellent.

#### 3.2.1.4.Percentage Weight loss

Samples were weighed by using Electric balance and calculate the percentage of weight loss as follow,

$$= \frac{\text{Initial Weight} - \text{Final Weight}}{\text{Initial Weight}} \times 100\%$$

### 3.2.2 Vacuum packing

The fresh fruit were weighed and packed in 200 gauge polyethylene bags. Before putting a rubber band the excess air in the bag was removed by using a inlet tube of a pump.

#### 3.2.2.1.Peel colour development

Peel color development, diseases, visual quality rating and percentage weight loss were recorded as sealed packages.

Then observations were taken 2 weeks interval for up to 2 months. Four replications were used for each sampling time.

### 3.2.3 Sealed Packaging

Fresh fruits were sealed in 300 gauge polyethylene bags by using polyethylene sealer. Observations were taken as above in 200 gauge polyethylene.

### 3.2.4 Vacuum Packaging

Fresh fruits were sealed with 300 gauge polyethylene bags by using rubber bands after exhausting the air in the PEB(s) and store in a cold room . Observations were recorded similar to above experiments.

## 3.3 Experimental Design and Analysis

The samples packed in 200 and 300 gauge polyethylene were subjected to four treatments (Sealed and vacumed packages) with four controls (perforated packages) in a completely randomized design (CRD) nested with replicates. The data were subjected to variance analysis using the SAS package. The data obtained for treatments were analyzed using the Duncan's multiple range test (DMRT).

CHAPTER 4

# 4.0 RESULTS AND DISCUSSION

## 4.1 Peel Colour

The peel colour of lime during storage at 8 – 10°C in cold storage presented in Table 4.1

1. Full green colour,
2. Colour break,
3. More Green than Yellow,
4. More Yellow than Green,
5. Full Yellow.

The maximum peel colour development was observed in control fruits stored in perforated polyethylene bags (PEB) starting from 2 weeks of storage (Table 4.1). It may be due to acceleration and uncontrolled ripening due to release of ethylene by decaying fruits (Salunke and Desai, 1984). Yellow colour development was continued to be increased through out the storage. The maximum peel colour was CI-5 at 08 weeks of storage. It can be seen from the table that lime stored in sealed PEB(s) (200 gauges) remained least affected even at 8 weeks of storage compared to those in all MA packages. Yellow colour development in MA packages of 300 gauge was significantly higher than that in 200 gauge MA packages. Peel colour development in lime is due to degradation of chlorophyll (Salunke and Desai, 1984). Ethylene hastens loss of chlorophyll from the peel during storage (Aharoni, 1968). When lime packed in MA chlorophyll degradation slowed down to a greater extent.

The lower levels of respiration when fruits stored at MA may have contributed to the lesser peel colour development (Grierson *et.al.,* 1966). It can be seen from the Table 4.1 that chlorophyll degradation has not been significantly delayed by low temperature alone. Poor performance in maintaining green colour in 300 gauge PEB may be due to carbon dioxide injuries. Higher incidence of $CO_2$ injuries were observed in 300 gauge PEB at latter part of storage.

**Table4.1-mean of the peal colour of lime stored at modified atmosphere at low temperature.**

| Treatments | Storage duration weeks | | | |
|---|---|---|---|---|
| | 2 weeks | 4 weeks | 6 weeks | 8 weeks |
| 200MA | 1.119B | 1.980C | 2.095C | 3.100C |
| 200VP | 1.166B | 1.633C | 2.486C | 4.200B |
| 300MA | 1.072B | 3.172B | 4.333B | 4.200B |
| 300VP | 1.066B | 3.086B | 4.146B | 2.750C |
| Control | 2.756A | 4.800A | 5.000A | 5.000A |

Treatment means in a column having a common letters are not significantly different by DMRT 5%. Each data point represents mean of 4 sample.

## 4.2 Diseases

The disease of lime during storage at 08 – $10^0$ C are presented in Table 4.2.

0. No disease,
1. Slightly disease less than 10%,
2. Moderate disease between 11% - 20%
3. High disease between 21% - 30%
4. Disease higher than 30%

The maximum disease development was observed in control fruits stored in perforated PEB starting from 2 weeks of storage (Table 4.2). Disease development was continued to increase throughout the storage. The maximum disease was DI 2 at 8 weeks of storage. But lime stored in sealed polyethylene bags (200 gauge) remained least affected at 8 weeks of storage compared to that in all MA packages. Disease development in MA packages of 300 gauge was significantly higher that in 200 gauge MA packages.

These diseases are caused by several species of fungi, which may be responsible for disease of other fresh fruits, however no serious post-harvest diseases of *Citrus* fruits have been attributed to bacteria (Fawcelt, 1993 and Smoot *et al.*, 1971). Development of post-harvest diseases in limes are initiated by infection of the fruit during the growing season, other disease originate in injuries which are created during harvest and subsequent handling of the fruit. It can be seen from the Table 4.2 that disease development has not been significantly delayed by low temperature alone. When lime was packed in MA storage, disease development slowed down to a greater extent. Poor performance in manifestation of physiological disorders in 300 gauge PEB may be due to carbon dioxide injuries. Higher incidence of $CO_2$ injuries were observed in 300 gauge PEB at latter part of the storage.

**Table 4.2-Mean percentage of diseases of lime storage at low temperature. (√ transformation)**

| Treatment | Storage duration | | | |
|---|---|---|---|---|
| | 2 weeks | 4 weeks | 6 weeks | 8 weeks |
| 200MA | 1.000A | 1.235A | 1.775A | 1.599B |
| 200VP | 1.000A | 1.013A | 1.376B | 1.162C |
| 300MA | 1.000A | 1.376A | 1.493B | 1.732B |
| 300VP | 1.000A | 1.521A | 1.862A | 1.746B |
| Control | 1.000A | 1.000A | 1.732A | 2.000A |

Treatment means in a column having a common letter(s) are not significant different by DMRT 5%. Each data point represents mean of four samples.

## 4.3 Visual Quality Rating (VQR)

Visual quality rating during storage at 8 – 10$^0$C is given in Table 4.3.

1-Not edible,
3-High defects can not be sold,
5-High defects but can not be sold,
7-Quality is defects moderate
9-Quality excellent.

The maximum VQR retardation of lime was observed in control fruits stored in perforated PEB starting from 2 weeks of storage (Table 4.3). VQR reduction was continued to be increased through out the storage. The maximum VQR was 4.00 at 8 weeks of storage. It can be seen from the table 4.3 that lime stored in sealed packaging MA in 200 gauge PEB remained least affected even at 8 weeks of storage compared to those in all MA packages. VQR reduction in MA packages of 300 gauge was significantly higher than that in 200 gauge MA packages. VQR retardation in lime is due to degradation of chlorophyll, physiological disorders and diseases. It can be seen from the table 3 that VQR retardation has not significantly delayed by low temperature alone. When limes were packed in MA, VQR retardation slowed down to a greater extent.

**Table 4.3- Mean percentage of VQR of lime stared at low temperature.**

| Treatment | Storage duration | | | |
|---|---|---|---|---|
| | 2 weeks | 4 weeks | 6 weeks | 8weeks |
| 200g MA | 9.000A | 7.146A | 5.081B | 6.550A |
| 200g VP | 9.000A | 8.793A | 6.816A | 5.600A |
| 300g MA | 9.000A | 5.466B | 6.589A | 5.900A |
| 300g VP | 9.000A | 5.593B | 1.800C | 5.500A |
| Control | 8.813A | 5.000B | 5.200B | 4.000B |

Treatments means in a column having a common letter(s) are not significantly different by DMRT 5%. Each data point represents mean of four samples.

## 4.4 Percentage of Weight Loss

The Percentage of weight loss of lime during storage at 8 – $10^0$ C in cold storage is presented in Table 4.4.

The maximum weight loss was observed in controlled fruits stored in perforated PEB starting from 2 weeks of storage (Table 4.4). Weight loss was continued to be increased throughout the storage. The maximum weight loss was 20.66% at 8 weeks of storage. It can be seen from table 4.4 that lime stored in all sealed and vacuumed PEB(s) (200 and 300 gauge) remained least affected even at 8 weeks of storage compared to those in rest of the packages.

**Table 4.4-Mean of percentage of weight loss of lime stand at low temperature.**

| Treatment | Storage duration | | | |
|---|---|---|---|---|
| | 2 weeks | 4 weeks | 6 weeks | 8 weeks |
| 200g MA | 1.83B | 2.27B | 2.83B | 1.16B |
| 200g VP | 1.10B | 1.91B | 2.63B | 0.30B |
| 300g MA | 0.97B | 2.80B | 1.55B | 1.05B |
| 300g VP | 0.72B | 2.47B | 4.72B | 1.36B |
| Control | 5.967A | 10.13A | 18.34A | 20.46A |

Treatment means in a column having a common letter(s) are not significantly different by DMRT 5%. Each data point represents mean of 4 samples.

## CHAPTER 5

### Conclusion:

The drastic price drop during the peak season of lime causes serious problem for farmer income. Results showed lime can be successfully be stored in sealed low density polyethylene bags at 8-10 $^0C$ for eight weeks. Lime harvested during peak period can therefore be stored for two months and released to the market, when price is high. Although vacuum packing theoretically must increased the storage life it was not observed with this lime. High physiological injuries observed may be carbon dioxide injuries due to higher level of carbon dioxide accumulated in the vacuum packed and 300 gauge bags. Further studies must be carried out to analyze the gas composition of the bag. If mature lime stored under modified atmosphere using sealed low-density 200 gauge polyethylene bags the storage life can be extended up to eight weeks at 8 - 10 $^0C$. This technology can therefore be adopted by storing lime during peak period at 8-10 $^0C$. These cold rooms can be constructed in major lime growing areas.

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