

**MODIFIED ATMOSPHERE PACKAGING OF MANGOES (*Mangifera indica* L.)
IN POLYMERIC FILMS**

Dissertation

Submitted to the Punjab Agricultural University
in partial fulfilment of the requirements for the degree of

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in

Processing and Agricultural Structures
(Minor subject: Food Science and Technology)

by

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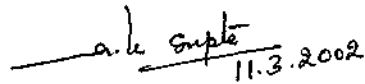
Dedicated

*to the sweet memory of my revered
father Late Shri Jagan Nath
Pharma who inculcated in me since
childhood the love of learning and
the spirit to work unrelentingly to
achieve my cherished objectives*

CERTIFICATE I

This is to certify that the dissertation entitled, "**Modified atmosphere packaging of mangoes (*Mangifera indica* L.) in polymeric films**" submitted for the degree of Ph.D. in the subject of Processing and Agricultural Structures (Minor subject: Food Science & Technology) of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Satish Kumar (L-98-AE-87-D)** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

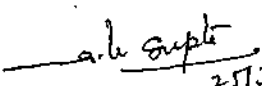

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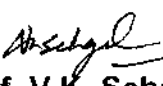
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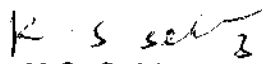
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CERTIFICATE II

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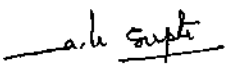
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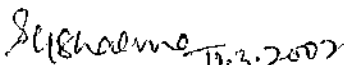
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ABSTRACT

The study on modified atmosphere packaging of mangoes was undertaken to evaluate the effect of type of polymeric film, thickness, perforation level on the shelf life of mangoes under different storage environments. The quality of mangoes was observed in terms of PLW, firmness, TSS, decay, shrinkage, pH, TSS/acidity ratio and colour development of skin. Based upon above parameters LDPE, 80 gauge film was found to be best packaging film for extending shelf life of mangoes upto 18-20 days with a total loss of about 20 per cent. Perforations resulted in retaining excellent colour and had marked superiority over other treatments. A perforation level of 5.4×10^{-3} and 1.08×10^{-2} per cent were found to provide optimum TSS/acid ratio in non-refrigerated and refrigerated storages, respectively. The thickness of the film had positive correlation with quality parameters. Simulated transportation studies revealed that shifting from traditional wooden boxes to CFB/plastic crates would entail a transportation loss reduction by 37-40 per cent. Simply film wrapping would result in loss reduction by about 60 per cent in any packaging box over control fruits. The CO_2 transmission rate of LDPE-80 film was found to be much higher than O_2 . Perforations resulted in more transmission of O_2 than CO_2 . Exchange of gases through perforations accounted for 97-98 per cent while film had 2-3 per cent of total gas exchange. Perforations resulted in drastically reducing the steady state times of O_2 while it did not much effected the steady state times of CO_2 gas. The increase in number of perforations and decrease in ambient RH resulted in little decrease in RH within the package but it remained above 95 per cent. An perforation area of around 2.7×10^{-3} per cent would give optimum levels of $\text{O}_2 \approx 6$ percent and $\text{CO}_2 \approx 9$ percent which will prevent the development of off flavours in the packaged mangoes.

Kay words: modified atmosphere, mango, packaging, perforation mathematical model, concentration, LDPE, simulated.


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LIST OF ABBREVIATIONS

| | | |
|-----------------|---|-------------------------------|
| RT storage | : | Room temperature storage |
| B&S storage | : | Brick and sand storage |
| CS | : | Cold storage |
| Hrs | : | Hours |
| LDPE/LD | : | Low density polyethylene |
| HDPE/HD | : | High density polyethylene |
| S-60 | : | Shrink film (Cryovac, D-955) |
| O ₂ | : | Oxygen |
| CO ₂ | : | Carbon dioxide |
| RH | : | Relative humidity |
| TL | : | Transportation loss |
| PLW | : | Physiological loss in weight |
| TSS | : | Total soluble solids |
| R1, R2..... | : | Replication No.1, No.2 |
| m | : | Meter |
| ml | : | Milliliter |
| RR | : | Respiration rate |
| MAP | : | Modified atmosphere packaging |
| SG | : | Specific gravity |

Chapter – I

INTRODUCTION

Mango (*Mangifera indica* L.) is one of the most important fruits in tropical and sub-tropical regions of the world and is rightly called king of fruits. It belongs to the family of *Anacardiaceae* genus *Mangifera*. It is reported to contain 41 species and 793 cultivars and is known to have originated in south east Asia (Ramteke *et al.*, 1999). Mango crop is grown commercially in 87 countries. Several hundred varieties existed in India but only 20 varieties are commercially grown (Chadha, 1988). India produces 13 million tonnes out of the total world output of 20 million tonnes of mangoes, of these barely 40,000 tonnes (0.31 percent) of fresh mangoes could be exported, bringing to the country in 1999, Rs.58 crores worth of foreign exchange (Swamy, 2001). This is mainly because no effective method has been employed to keep fruits in good conditions. The actual potential of mango exports is 680 crores which would mean exporting nearly half million tonnes of mangoes or nearly 12 times the present exports. As far Indian canned mango products, only 20,000 metric tonnes could be exported in 1996-97. Further, India accounts for just 3 percent of the \$72 million imports of mangoes by the European Union (Singhal, 1999). Japan imposed ban on imports of mangoes from India because of fruit fly infestation. Thus, bulk of the fruit produced is consumed in the domestic market.

Mango season is from April to August with a peak arrival period of middle of May to middle of July. It is when temperature is very high leading to very high post-harvest losses which vary in different varieties. Madan and Subramanyan (1988) estimated a loss of about 20 percent in Neelum, 22 percent in Banganpalli 30 percent in Dashehari and 36.7 percent in Totapuri. Normally mango fruit takes about 5 days under tropical conditions to ripen and become over ripe after 7-8 days. So it becomes difficult to transport mangoes to a distant market. Mango fruits are traditionally packed in wooden boxes of 10 kg capacity, transported and stored. Due to impact, shock and vibrations, the nails come out and puncture the fruits resulting in a mechanical damage of 14-20 percent (Singh and Verma, 1995). More recently CFB boxes are also being practiced but only on a small scale. Although CFB boxes results in reducing the mechanical damage to 4-8 percent compared to 14-20 percent in wooden boxes, but post-harvest physiological loss in weight are generally the same. Here a new technique called individual wrapping of fruits and vegetables in polymeric films has been found to be beneficial in reducing mechanical damage during transportation and physiological loss in weight during storage. Most of the work has been done either on packaging and storage of mangoes in wooden and CFB boxes under ambient conditions or cold storage of film wrapped mangoes. The work on storage of individually wrapped mangoes under ambient conditions has rather been limited especially in perforated films.

Packaging of fruits and vegetables in polymeric films results in high RH within package environment which diminishes dehydration and preserves freshness (Ben-Yehoshua, 1987, Ben-Yehoshua *et al.*, 1994). Low O₂ and elevated CO₂ concentrations within the package reduces the respiration rate and hence enhances the shelf-life of the fruits. However, fruits have different tolerance levels for gases which may effect the fruits quality. For mangoes required levels are O₂: 3-5 percent; CO₂:5-10 percent (Yahia and Kader, 1997). Thus lower O₂ levels and excessive CO₂ levels would result in development of off flavours in mangoes. Similarly, excessive in package humidity may stimulate microbial pathogens development. Therefore, MA package must be designed to provide optimum levels of gases which would ensure proper ripening of mangoes at the same time, should maintain in package humidity high enough to minimize weight loss. Most of the polymeric films commercially available does not provide the required levels of gases and water vapours. Therefore, there is a need to make perforations in films to increase the O₂ concentrations and lower load of CO₂ concentrations without much effecting the RH within the package. The use of perforated films was recommended for mangoes by Shapiro *et al.* (1989), Fishman *et al.* (1996), and later tested experimentally by Rodov *et al.* (1994); Yantarassi *et al.* (1994). The optimal conditions for mango packaging could be determined with the aid of a model which would include consideration of film perforations. Investigations of gas exchange through perforated films was undertaken by Emond *et al.* (1991) to find alternative to diffusivity coefficient

and Fishman *et al.* (1996) measured gas and moisture transport through perforations and developed descriptive empirical equations based on measurements. Similar models were developed by Shirazi and Cameron (1992) and Fishman *et al.* (1995). All these models have been developed and applied under cold storage/CA storage conditions. The work under variable ambient conditions has not yet been done. Keeping in view the above points, the present investigations has been planned with the following objectives:

1. To study the effect of packaging in different polymeric films on the quality of mangoes. Physiological loss in weight (PLW), firmness, total soluble solids (TSS), shrinkage, decay.
2. To determine the best polymeric film for reducing the post-harvest losses and prolonging the shelf-life of mango fruits.
3. To develop suitable mathematical relationship between levels of perforation, O₂ concentrations and relative humidity inside the pack.

REVIEW OF LITERATURE

Mangoes are highly perishable commodity and are harvested when fully mature and unripe. The development of typical aroma and taste depends on the stage of maturity, care in handling during transport and method of storage. The quality of the fruit influences marketing and processing, on which depends the return of the grower. Incorrect practices lead to bruising of the fruit, which in turn not only increases respiration rate and metabolic activities but also facilitates the entry of spoilage micro-organisms. Thus, mangoes should be harvested at proper stage of maturity, graded, packaged and transported for better marketing and storage.

Respiration rate of the sound fruit is measured in terms of O_2 consumed or CO_2 produced. During respiration food reserves like sugars are utilized. Thus, respiration determines the shelf life of the fruit. So long as the fruit is on the tree, it receives its food from the parent tree and recoups losses due to respiration. Once the fruit is harvested, it has to utilize its own reserves for vital physiological processes. Thus, any treatment or conditions which increases the respiration rate will logically reduce the resistance of the fruit against microbial attack or shorten the storage and market life. At the same time in the complete absence of O_2 , anaerobic respiration starts and the fruit is fermented and spoiled. Thus, minimum O_2 required for aerobic respiration will be necessary and is termed as critical rate of respiration. It is thus essential to control fruit respiration to minimum so that freshness and

quality are retained for longer durations. The following factors affect the respiration rate during harvesting handling, packaging, storage and transportation (Anon, 1967).

Maturity Indices: Although there are number of indices which are used to determine fruit maturity at harvest. A summary of these are : specific gravity : 1.00-1.04, TSS : > 7.00, starch : 9 percent, size : medium size (remove over and under size, 140-225 gm), colour : light green to light yellow at stem end side. Days of harvest varies from variety to variety (Dashehari 95-105 days).

Variety : Generally, early maturing varieties have higher rate of respiration as compared to late maturing. Some varieties because of their low initial respiration, behave better during storage as compared to others.

Agronomic factors : Fruits in an orchard which receives lesser amount of organic manure compared to inorganic fertilizers show higher respiration rate. A higher nitrogen supply to the soil increases respiration of the fruits and hence, poor storage qualities.

Age of the fruit: The age of the fruit denotes the time that has elapsed after harvest and can be divided into pre-storage and post-storage life. The respiration rate during pre-storage is minimum, attaining its peak during storage, followed by fall denoting senescence. Therefore, the best stage of fruits to be transported is when they are green and hard. Avoid transporting ripe fruits.

Temperature : If the fruits are subjected to higher temperature even for a short duration, the respiration rate rises, resulting in reduction of subsequent storage life and heavy spoilage during transit. Avoid storing them in large heaps or exposing them to sun.

Ventilation: Proper ventilation neutralizes the heat and humidity generated during respiration; thus providing a cooling effect which further reduces the respiration rate.

Influence of micro-organism : The enzymes liberated by spores of micro-organisms make the skin weaker and render their penetration more easier. These microbes serves as focus of infection to other healthy fruits. This spore load increases the respiration rate of the fruits. Ethylene produced by fungal spores helps in quick ripening and makes mangoes more susceptible to decay.

Influence of mechanical injury: On injury, the respiration rate of the fruit considerably increases and the damaged cells are prone to microbial attack. Throwing fruits, damages the fruit cells. Though this type of cellular damage is not outwardly perceptible, the injured cells respire at a very fast rate and deterioration sets in quickly. Rough handling of fruits should be avoided. The top one-third of the fruit at stem end side respire at a higher rate than its other portions. Thus, respiration rate is an index of metabolic activity of the fruit on which depends the ripening and development of taste and flavour.

Artificial ripening: Some varieties which remain green even after ripening can be treated with calcium carbide to bring out yellow colour. But such treatments does not influence other metabolic changes including sugar : acid ratio. The flesh will become yellow. It will require usual ripening time even after calcium carbide treatments. The usual practice should be let the fruit ripen normally and this treatment may then follow to turn them yellow and attractive. This treatment is of respiratory nature and is more pronounced in pre-climacteric stages than post-climacteric stage. Any concentration 10 times the 1:10,000 dose causes brown lesions around the lenticels.

The literature available on harvesting, packaging, transportation, storage and mathematical modelling has been reviewed and is discussed as under:

2.1 Mango harvesting, transportation, modified atmosphere packaging and storage

Lakshminarayana (1973) investigated respiration and ripening pattern in the life cycle of mango fruits. It was reported that fruits picked during early and later stages of development showed respiration climacteric within 6-10 days whereas, for those picked during middle stages, it occurs after 10 days. It was recommended that harvesting fruits before they are fully mature, anytime after stone has fully hardened, would be beneficial in reducing pre-harvest fruit drop and post-harvest spoilage.

Dhatt (1979) studied the relationship of various fruit characteristics with maturity in Dashehari mango. It was observed that changes in specific gravity, starch, TSS, acidity and tannins in the fruits are the suitable indices for judging the maturity in Dashehari mangoes. A minimum specific gravity of 1.00 and starch of 9 per cent was recommended as necessary for proper maturity of the fruit.

Rao *et al.* (1979) studied the fruit maturity standards of Dashehari mango. It was observed that there was no indication of maturity from specific gravity. The fruits having TSS : 8.5: acidity : 0.3 percent were found to be good indicators of fruit maturity such fruits after ripening attained good quality with TSS : 22 percent; acidity : 0.13 per cent.

Shukla and Bajpai (1979) investigated the maturity standards and storage of mangoes using different treatments, viz., control, waxing, pre-

cooling, hot water and maleic treatments etc. and then storing under room temperatures and cold storage conditions. It was found that colour, TSS, acidity, sugars, starch and respiration rate are positively correlated with harvesting maturity. Again pre-cooled and wax treated mangoes gave minimum PLW, maximum acidity under both storage environments. However, TSS and total sugar remained low. Minimum respiration rate was observed in above treatments which helped in increasing storage life of fruit to 13 and 40 days in respective storages.

Shyamamma *et al.* (1995) reported the use of external parameters for judging maturity and thus avoiding destructive sampling. In a study conducted to determine maturity indices for mallika mangoes, heat units of 1216 ± 42 cumulative degree days (CDD), at 115 days after fruit set and lenticel morphology (brown colour with sunken centre) and density were found to be more reliable indices.

Joshi and Roy (1985) studied the effect of integrated post harvest handling on bio-chemical changes in Alphonso mango fruits packed in conventional wooden crates, transported by both rail and road and stored at ambient temperature of $26.4-32.4^{\circ}\text{C}$ and RH of 36-64 percent. The chemical constituents like TSS, starch, sugars, total carotenoids pigments and pH were found positively correlated whereas moisture content, acidity, ascorbic acid and tanins were negatively correlated with fruit sp. gv. At the time of harvest. The mangoes with sp.gv 1.00 – 1.04 were found to be best as far as both shelf life and nutritive value were concerned.

Roy and Joshi (1988) reported an approach to integrate post-harvest handling of mango. Mangoes of different specific gravity were taken, treated with both chemicals and water (5 combinations) and then packed in wooden crates, CFB boxes with partitions with dry grass and paper cuttings as cushioning materials. These were stored under ambient and cold storage conditions. It was found that 80 per cent of the fruits were matured having specific gravity greater than 1.00. Among post-harvest treatments bavistin (1000ppm) and hot water dip (52°C, 5 min) were adjudged the most effective from the point of view of shelf-life. Out of different packagings tried, CFB boxes with partitions was best w.r.t. bruising, during transportation and PLW, ripening intensity and spoilage during storage.

Joshi and Roy (1986) reported CFB box as effective alternative to wooden crates for transport and storage of mangoes. Mangoes packed in CFB boxes with partitions, CFB box with trays and conventional wooden boxes with dry grass and paper cuttings as cushioning material, were stored under room temperature (25-32.2°C, 44-76 percent) and cold storage (10±1°C, 85-90 percent) conditions. Fruits packed and stored in CFB boxes exhibited less bruising during transport and slow rate of ripening, spoilage, shriveling and PLW compared to those in wooden crates.

Narayana *et al.* (1989) undertook an investigation on use of HDPE films (10,15,25,32.5µ) in transit of mangoes. Individual packed mangoes

kept in bamboo baskets using paddy straw as cushioning material were transported to a distance of 1700km by road and train. All the wrapped fruits were green and extent of greenness was directly proportional to thicknesses of the film, while non-wrapped fruits had considerable ripening. The rate of ripening and TSS and carotenoids were increasing at a slower rate than control fruits.

Verma and Prakash (1995) undertook an investigation to quantify the losses during transportation. Different transportation practices were studied viz. transportation by piling them loose on the floor of the truck, packing in wooden boxes and stacking on the truck. While the aggregate losses due to transportation in case of the former was 15.80 percent, it was 17.53 per cent in case of later. Inferior appearance and significant shrinkage of fruit due to excessive exposure was observed in the loose transport of mangoes. It was emphasized to dispense with the practice of over filling of boxes and improvement in packaging boxes and transportation truck suspension system to minimize losses.

Kapse *et al.* (1997) studied the long distance transportation of mangoes: Mangoes were graded in 4 specific gravity (SG) groups, packed in CFB box and wooden crates, transported by truck to a distance of 1150 km and then stored under ambient conditions. It was observed that fruits with specific gravity 1.00-1.04 have the best quality. The fruits with $SG < 1.00$ did not ripen properly while those with $SG > 1.04$ recorded earlier ripening (8 days) and lowest shelf-life (10.5 days). The fruits packed in

CFB boxes showed reduced PLW, extended shelf life and better organoleptic qualities than those stored in wooden crates.

Raghav (2000) investigated simulated transport of kinnow packed in polymeric films. It was concluded that paper shattering is best cushioning material. Among different packages, 7-ply CFB box was found to be best, followed by 5-ply CFB box, plastic crate and wooden box.

Rameshwar *et al.* (1979C) reported the use of film wrapping with ethylene absorbent for extending the storage life of mangoes. Fruits were wrapped in 200gauge polyethylene bags with 0.4 percent ventilation plus ethylene absorbent. It was found that film wrapping resulted in more spoilage due to greater incidence of disease. Stem end rot was found to be major disease in wrapped mangoes. Colour development was slower. Film wrapping decreased TSS and tended to lower acid loss during ripening. Organoleptic tests indicated no-off flavours.

Based on steady state data, Ben-yehoshua *et al.* (1983) observed that waxing increases the resistance of fruit to water vapour by 25 percent but raises the resistance to CO₂, O₂ and ethylene by 140 percent, 250 and 100 percent, respectively. Conversely, seal packaging was found to raise the resistance to water vapour by 1375 percent. However, resistance to CO₂, O₂ and ethylene was raised by only 72, 233 and 25 percent respectively. These differences were impressive considering that film has 10-20µm thicknesses and waxing produces a membrane with an average thicknesses of 1µm.

Roy *et al.* (1985) studied the effects of hot water (52, 55, 58±1°C) with captan (0.5 percent, 5 min) on the storage life and quality of mangoes cv. Langra and Safderpasand. It was concluded that the economic storage life of treated mangoes could be extended by 3-4 days at ambient temperature of 32±2°C. Hot water treatment greatly reduced spoilage by stem end rot. The retarded ripening was shown by slower increase in TSS and sugar content and better retention of ascorbic acid.

Kaira *et al.* (1986) conducted experiments for improving quality of Dashehari mangoes through pre-packing. Mangoes in a lot of three were wrapped in newspaper, polyethylene, brown paper and butter paper, pouches. It was found that PLW in polyethylene packed mangoes was very less (5 percent) compared to other packing materials (15-20 percent) after 8 days of storage. Polyethylene reported no ripening, and about 40 percent spoilage. The other treatments showed complete ripening, optimum level of TSS and acidity.

Miller *et al.* (1986) reported that off flavours in film wrapped produce may be related to excessive levels of CO₂ and reduced levels of O₂. It was found that mangoes shrink wrapped in 12.7µm HDPE at soft ripe stage had off flavours and elevated CO₂ levels after 9 days of storage.

Kaira *et al.* (1988) studied the effect of post-harvest treatments with TBZ and two wax emulsion formulations on the ripening behaviour of mangoes under ambient conditions for 12 days. The TBZ treated fruits resulted in best appearance and Frutoz treated fruits least attractive on 6th

day of storage. Thereafter vapour gard treated fruits remained best with lesser spoilage, better organoleptic score and good ripening as indicated by firmness of 4.0 lb/in² and inhibited senescence. Moisture, reducing sugar and β -carotene differed significantly while TSS, acidity and total soluble sugars showed insignificant difference among all the treatments.

Reddy and Raju (1988) studied the effects of pre-packaging and post-harvest treatments on the storage behaviour of mango fruits. Fruits were sealed in polyethylene bags of 100, 150, 200 gauge thicknesses with 10 and 20 vents. Fruits were treated with 3 systemic fungicides and 4 levels of wax emulsions and their combinations. Mangoes treated with 100ppm thiobendazole with 6 per cent wax emulsions recorded the least spoilage during 20 days of storage. Mangoes stored in 150 gauge bags with 10 vents recorded the least PLW (9.53 percent) compared to control (15.08 percent) during entire period of storage.

Geeson (1989) explained the importance of matching product respiration requirements and film permeability to gases and water vapour. The examples of successful application of MAP using suitable permeable or micro-perforated plastic films which can extend shelf-life without adverse effects on eating quality, are illustrated by studies on apples, leeks, pepper and tomatoes.

Raise (1989) reviewed the literature on individual film wrapping of florida fresh fruits and vegetables. It was reported that film wrapping reduces weight loss, colour development, chilling injury; and maintains

firmness and internal quality even under optimum storage conditions. At higher than optimum storage temperature, these advantages would be more pronounced. The disadvantages like off flavour and accelerated decay were also studied. It was concluded that advantages of film wrapping for high quality produce at premium prices generally outweigh the disadvantages.

Roy and Pal (1989) carried research on low cost zero energy cool chambers for short-term storage of mango. These chambers were able to maintain fruit firmness by lowering PLW and other metabolic processes. Eventually, 3 to 4 days more shelf-life of mangoes could be obtained in cool chambers compared to ambient conditions. Further, a 500 ppm bavistin dip helped in checking the microbial infection. Fruits had excellent texture in cool chambers yet scored low organoleptic value due to less sugars and carotenoids. However, ripe mangoes when stored in cool chambers had 9 days shelf-life and high organoleptic values.

Sahni and Khurdiya (1989) stated that stage of ripening of fruit has a considerable bearing on the physico-chemical constituents of the fruit and ultimately on the quality of the processed products in terms of colour, flavour and texture. An increase in pH, TSS, carotenoid and sugars was observed in the ripe fruits while firmness, specific gravity, acidity and ascorbic acid, declined. Total soluble solids, carotenoids and sugars reached maximum values in the fruits ripened from 6th to 9th day and thereafter they declined.

McCollum *et al.* (1992) evaluated the effects of individual shrink film wrapping (60 gauge) on shelf-life and quality of mangoes. The fruits were stored at 12°C for 1-2 weeks followed by storing at 21°C for ripening. The PLW was 0.6 and 6.6 percent after 14 days of storage in wrapped and non-wrapped fruits respectively. Wrapped fruits were significantly more acidic than were non-wrapped as indicated by lower pH value. However, wrapped fruits showed more decay than non-wrapped.

Batagurki *et al.* (1995) investigated the individual packaging of mangoes in two polymeric films (with and without perforations) for short-term storage at ambient temperature of 21-24°C. It was observed that packaging improved the quality of the product. Mangoes packed in perforated cryovac bags were found to have better quality than those in E50 bags. The physiological loss in weight in packed mangoes were 1.64-2.98 percent as compared to 11.50-17 percent in non-packed fruit upto 10 days of storage.

Hudder *et al.* (1995) studied the influence of post-harvest hot water and bvestin treatments on ripening, spoilage and physico-chemical constituents of Alphonso mango. Fruits were treated with hot water for 52±1°C for 2.5, 5.0, 7.5 min. with or without the addition of Bavistin (500,1000ppm). Hot water treatments for 5 min at 500 ppm Bavistin was found to be most ideal with respect to post-harvest disease control and fruit quality. Hot water treatments significantly enhanced the ripening

process. A treatment time of 7.5 minutes resulted in wrinkled appearance and thus badly affected the fruit quality.

Mahajan and Sharma (1996) tried different concentrations of calcium chloride (2,4,6,8 percent) as post-harvest treatments on the harvested Dashehari fruits. These treated fruits were packed in wooden boxes and stored at room temperature ($30\pm 2^{\circ}\text{C}$, 60-65 percentRH), calcium chloride (6 percent) turned out to be most effective treatment in reducing the PLW and in improving colour and quality of fruit. Fruit of this treatment were marketable even after 12 days of storage as compared to 7 days in control fruits.

Sagar and Khurdiya (1996) conducted experiments to find out optimum stage for fresh consumption. Fully mature and unripe Dashehari mangoes were wrapped in newspaper and kept under ambient temperature ($33-35.5^{\circ}\text{C}$). At each successive stage of ripening TSS, total carotenoids reducing and total sugars increased but firmness specific gravity and vitamin C reduced. The fruits achieved optimum ripening in about 6 days of storage with pulp firmness of 1.54 kg/cm^2 , TSS: 15°Brix, reducing sugars : 5 percent and vitamin C : 29.25 mg/100gm. The sensory quality score increased with duration of storage upto 6th day and then declined due to over ripening.

The fruits of mango cultivar were subjected to hydro-thermal disinfection treatment by Gutierrez *et al.* (1997) and then stored at temperature 6°C and 12°C and RH : 75-80 percent for upto 24 days. It was

concluded that hydrothermal treatment did not alter ripening patterns in terms of TSS, acidity, firmness, sugar content, respiration, etc. and susceptibility to chilling injury of mangoes. The chilling injury occurred after 16, 20th day of storage at 6° and 12°C temperature respectively. Increase in respiratory activity appeared to be potential index for monitoring chilling injury in mangoes.

Manzano *et al.* (1997) carried out experiments on coating waxes on Haden mangoes. Mangoes were wax treated and stored at 12, 18 or 25°C for upto 20 days. The L and chroma values were higher in treated fruits than control fruits. Hue values remained close to zero throughout storage. Ethylene application and waxing resulted in good colour and uniform ripening after 20 days of storage at 12 or 18°C.

Martinez *et al.* (1997) investigated the optimization of storage procedure of mango cv. Azucar. Effect of temperature, chemical, wax and heat treatments and vacuum packings was studied. It was found that the maximum number of days that fruit could be stored at 29,18,9°C were 3-8, 10-27 and 15-40 days respectively. Pre-cooling did not affect the storage duration. But resulted in a fruit having better appearance and slower ripening. Storage at 9°C was found to be best.

Raje *et al.* (1997) studied the post-harvest preservation of mangoes by controlled chemical release agents and adsorbent. Alphonso fruits were stored at 32-36°C and 70-75 percent RH in CFB cartons with four ethylene absorbers or destructors chemicals. Ethysord doubled the shelf-life of

mangoes (16 days) compared to control (8 days) with minimum PLW, highest sensory score and lowest microbial load. A combination of ethysord and SO₂ releaser achieved the best results.

Trinidad *et al.* (1997) reported that controlled atmosphere (CO₂ : 5-10 percent, O₂ : 5 percent) storage did not extending the storage life of kent mangoes. The mangoes were stored at 13°C in air as well as controlled atmosphere for 25 days. No significant difference in TSS, acidity, firmness, colour, PLW and aroma was found among all treatments. Tests indicated off flavours in mangoes after 21 days in both methods of storage.

Research on modified atmosphere and controlled atmosphere storage of mangoes has been reviewed by Yahia and Kader (1997). The optimum atmosphere composition is reported as 3-5 percent O₂ and 5-10 percent CO₂. These atmospheres could delay ripening but the benefits were not very significant. It was suggested that CA and MA would probably be beneficial in delaying fruit ripening during long distance sea transport for two or more weeks. Keitt mangoes being very tolerant of insecticidal atmosphere had potential commercial feasibility.

Waskar *et al.* (1997) studied the effect of method of harvesting on post-harvest loss reduction and shelf-life extension of mangoes. Mangoes were harvested with two methods : hand harvesting without stalks or harvested with 2.5 cm stalks, using 4 different harvesters. The fruits were graded and packed in CFB boxes and stored under ambient conditions

(24.1-38.1°C, 42.2-81.3 percent RH). It was found that harvester increased the harvesting capacity and delayed ripening and shriveling in fruits with stalks. Mechanical harvesting reduced PLW (13 percent) and spoilage (0 percent) compared to control (17.2 percent, 21.8 percent, respectively) while extending the shelf-life by 4 days.

Zambrano *et al.* (1997) studied the changes during storage of wax-coated mango fruits. Mangoes dipped in 1 percent aqueous suspensions of prolong or prima fresh were placed in 20 liter plastic containers and stored at 15°C and 85-95 percent RH. Non-significant affects were observed in the external colour, but coatings affected internal colour. Analysis indicated that composition was affected to some extent. PLW in treated fruit was less compared to untreated.

Gonzalez *et al.* (1995) investigated low O₂ treatment before storage in normal or modified atmosphere packaging of mangoes. It was observed that both CA and MA delayed losses of weight and firmness. Fruits maintained good appearance. However, some fruits in two of the three films used, developed off-flavour after 10 days of storage at 20°C.

Singh and Narayan (1995) investigated the effect of different levels of ventilation (0, 0.25, 0.50, 1.00 percent) in polyethylene bags (200 gauge) on the quality and shelf-life of Dashehari mangoes. It was concluded that packaging of fruits in ventilated bags extended the storage life and marketability and preserved quality better than control upto 10 days. No significant differences were observed in the quality of fruits

having 0.50 and 1.00 per cent perforations. Fruits packed in wooden boxes could be stored for 8 days. A perforation level of 0.50 percent was recommended to prevent fermentation in Dashehari mangoes.

Yantarasri *et al.* (1995) reported that most non-perforated films are not sufficiently permeable to O₂ exchange to allow proper ripening. The study revealed that fruits wrapped in polystyrene trays (3 fruits/pack) with perforation area 7 percent and stored at 20°C, resulted in uniform ripening and prevented off flavour in mangoes. Non-perforated individually sealed mangoes had an extended shelf-life of 4-6 weeks, by preventing over ripening.

Ben-yehoshua *et al.* (1996) stated that perforation can be used to regulate atmosphere composition and water condensation in the package without a significant increase in PLW. Bell pepper and mangoes packaged in perforated films lost less weight and maintained higher quality than non-wrapped and at the same time demonstrated lower decay than in non-perforated packages. The ripening process was more regulated. Thus perforated packaging of mangoes and peppers retained most of the advantages of the non-perforated package.

Macnish *et al.* (1997) described the relationship between in package RH, weight loss, ripening of kensington pride mangoes and level of perforation. Fruits were held at 20°C in sealed plastic containers (1.2 litre bucket) having single circular hole ranging from 5-135 mm diameters. These holes resulted in variable RH from 57 to 83 percent. The PLW rates

ranged between 4-9 mg/g in respective treatments. Fruits softening and ripening was similar across all RHs.

Rodov *et al.* (1997) reported that a series of modified atmosphere package, with different steady state levels of O₂ and CO₂, could be obtained by varying the perforation area from 1 to 69mm². This system allowed regulation of ripening rates so that they correspond with the desired duration of storage and transportation. Packaging Tommy Atkins mangoes in perforated polyethylene films delayed, spoilage, allowed normal ripening, reduce PLW by 50 percent and prevented shriveling. Irreversibly impaired ripening and fermentation were observed in non-perforated films.

2.2 Mathematical modelling as applied to fruits and vegetables:

Bhullar and Farnaham (1980) reported that increase in the thicknesses of polyethylene bags was associated with a reduction in their permeability to moisture and gas; thereby reducing PLW probably due to a reduction in the moisture loss and respiration of the produce. Polyethylene packaging maintained higher humidity inside the package which in turn, slowed down the process of evapo-transpiration and proper balance of CO₂ and O₂ concentrations. Which further slowed down the respiration process (Hardenburg, 1971).

For many fruits and vegetables, the respiration rate and water production rate doubled with a 5°C rise (Hardenburg, *et al.*, 1986) but this rise would increase water vapour permeance of the film by only 23 per

cent (for an activation energy of 6.22). This implied that although a bag may adequately increase its OTR to keep a product aerobic for a given storage temperature rise, it may not adequately increase its water vapour permeance to prevent free moisture build up in the bag, which would encourage spoilage (Zagory and Kader, 1988, Shirazi and Cameron, 1992). Based on the above average activation energies, the temperature rise required to double gas transmission rate was OTR : 12.3°C; CO₂ TR : 13.9°C and for WVTR : 17.6°C.

Zagory and Kader (1988) emphasized the need of maintenance of produce quality through modification of atmosphere surrounding the product. They described the films for MAP and compared several mathematical models of atmosphere modifications and also indicated permeability values of 7700-77000 and 3900-13000 cc/m²/mil/day at atmosphere for CO₂ and O₂ gases in LDPE films and 7700-21000 and 1300-6400 cc/m²/mil/day at 1 atmosphere for CO₂ and O₂ gases in polypropylene films.

Anonymous (1992) produced first controlled respiration and ethylene absorption polyethylene film (Fresha – Pac). This type of film is produced with different permeation and absorption rates to suit a wide range of vegetables, fruits and cut flowers for shipping and arrival fresh in the world.

Christie *et al.* (1995) determined the film permeability by using the new material balance equation method under the conditions in which the

produce is to be stored. They also measured O₂ consumption, CO₂ and ethylene production at 8.8 ml/kg/hr, 9ml/kg/hr and 0.04μl/kg/hr, respectively for broccoli stored in MAP (CO₂ : 6 percent, O₂ : 1.5 percent) at 1.5°C. They recommended mixed gas cell method to have realistic prediction of film permeabilities.

Clarke *et al.* (1997) suggested MA storage in films with higher permeability, more responsive film to increase temperature, in which the relative permeability of CO₂ to O₂ can be altered i.e., membrane technology. The increase in permeability reduced the chance of the package becoming anaerobic during incidents of temperature abuse or when the cold chain was broken.

Moyls (1998) described whole bag method as more accurate, flexible, fast, easy and comparatively less expensive method for WVTR for the entire bag surface rather than for a small piece. WVTR can be determined at any desired temperature. However, it requires a supply of air at constant RH and temperature for more reliable results for polyethylene and other hydrophobic films.

Moyls *et al.* (1998) evaluated nine type of polyethylene films for modified atmosphere packaging for O₂, CO₂ and water vapour transmission rate at four temperatures (0,5,15.5, 23.2°C) and have shown that the average ratio of CO₂, TR/OTR decreased from 5.93 to 5.26 as temperature increased from 0 to 23.2°C while the average ratio of water vapour/O₂ permeance (on molar bases) decreased from 80.7 to 47. Again

the increase in temperature from 0 to 23°C affected the OTR, the most (compared value at 0 °C) followed by a slightly smaller effect on CO₂ TR (87 percent) and considerably smaller effect on WVTR (69 percent).

Jurin and Karel (1963) studied the optimum packaging conditions for apples and banana. For a particular package characteristics, the steady state O₂ concentrations was determined by solving the respiration permeation equation graphically. The point of inter-section of permeation curve and respiration curve gave the steady state level of O₂ concentration.

Veeraju and Karel (1966) used two films of different permeabilities for controlling oxygen and carbondioxide levels in a package containing apples. They simultaneously solved the following two equations, while using respiration rates, as needed, from experimental curves for R_o and R_c:

$$R_o.W = (K_1A_1 + K_2A_2) (C_A - C_i)_{O_2}$$

$$R_c.W = (K_3A_1 + K_4A_2) (C_A - C_i)_{CO_2}$$

Where, A₁ and A₂ are surface areas of two films C_A, C_i are gas concentrations outside and inside the package; K₁-K₄ are permeability coefficient for two gases and two films, respectively.

Hayakawa *et al.* (1975) obtained analytical formulae for estimating transient and steady state gas concentration in fresh tomato and banana packages. These formulae derived from ordinary differential equations by assuming that the rate of O₂ consumption or CO₂ evolution is influenced by

O₂ and CO₂ concentrations in surrounding atmosphere. These formulae are also useful in estimating equilibrium time values for gas exchange in packages. There was fair agreement between mathematical and experimental gas concentration and time values except time values for CO₂ gas. These analytical formulae are greatly useful for optimization of packaging parameters also as these are explicitly included in the formulae.

Henig and Gilbert (1975) developed two computer based differential equations representing change in O₂ and CO₂ concentrations with time. He reported a change in O₂ equilibrium concentrations from 5.42 to 9.5 per cent when packaging film area was changed from 40 to 95 sq. inch. Lowering in temperature from 23 °C to 15 °C resulted in reduction in O₂ consumption rate from 23 to 15.5 cc/kg/hr and reduced the film permeation. The proposed methods and computer solution provided a rapid and accurate way of predicting equilibrium concentration of O₂ and CO₂. Inflexible packages, the free volume of the packages change is reported with time whereas, the total pressure remained constant (Mannapperuma and Singh, 1987)

Hue angle and a/b ratio are two widely used parameters to study colour change during ripening. Thorne and Alvarez (1982) proposed the following mathematical functions between a/b and storage temperature to describe the surface colour development in tomatoes:

$$f(a/b) = \frac{(a/b)_t - (a/b)_g}{(a/b)_r - (a/b)_t} = \exp [C_0 + M(T).t]$$

where $M(T)$ = colour development index as a function of temperature

$$= \frac{C_1}{(C_2 - T)}$$

and a, b are hunter colour values; C_0, C_1, C_2 are constants of equations estimated from experiments. t, g, r are any colour, green and red stage, respectively.

Yang and Chhinnan (1987) proposed a similar model to describe surface colour development in tomatoes as a function of a/b and gas composition.

$$f(a/b) = \frac{(a/b)_t - (a/b)_g}{(a/b)_t - (a/b)_t} = \exp [C_0 + M(G).t]$$

$M(G)$ = colour development index and is a function of gas composition

The empirical model predicted colour development rate in tomatoes stored in constant and varying gaseous environment. Tomatoes were subjected to 20 different gas environments involving O_2 : 5-20 percent, CO_2 , 0-20 percent, respectively. $M(G)$ for each gas composition was determined. Regression analysis of M values yielded the coefficient of empirical equation.

Yang and Chinnan (1988) modelled the effect of O₂ and CO₂ on respiration and quality of stored tomatoes. Tomatoes were stored at 21°C and under 20 gas environments involving O₂ and CO₂ concentration of 5 to 20 percent respectively. The contours of firmness were plotted as a function of CO₂ and O₂. The following mathematical relation between gas concentration and firmness of fruit.

$$F = 59.92 + 54.03 C_c - 427.1 C_o + 1098 C_o^2 + 135.9 C_c^2 + 58.02 C_o C_c$$

Where C_o, C_c are O₂ and CO₂ concentration respectively. It was observed that changes in O₂ concentration has more pronounced effect on firmness than CO₂. Also flavour of the product is more related to O₂ concentration.

Cameron *et al.* (1989) developed a method for determination of O₂ consumption as a function of O₂ concentration by mathematical characterization of O₂ depletion with time by a tomato fruit in a closed system. Mathematical equation describing O₂ consumption as a function of O₂ concentration were developed for breaker, pink and red stages of tomatoes and were used to model film permeability coefficient to O₂, surface area and thicknesses as a function of fruit weight to achieve desired level of O₂ concentration. Equations were also developed to describe time to reach steady state using step wise numerical integration approach as suggested by Hayakawa (1975).

Emond *et al.* (1991) used the term effective permeability instead of diffusivity to determine gas exchange through perforation.

$$C_t = C_i - (C_o - C_i) e^{- (k_p \cdot t/v)}$$

Where, C_1 , C_0 refers to gas concentration inside and outside the package; k_p^* is effective permeability. An empirical equation was developed for effective permeability (k_p^*) to O_2/CO_2 as a function of area, thicknesses and temperature using step-wise procedure of the SAS statistical package.

$$K_p^* = a_1 + a_2 (d_p) + a_3 (E_p) + a_4 (T) + a_5 (d_p)^2 + a_6 (E_p)^2 + a_7 (T)^2 + a_8 (d_p)^2 E_p + a_9 (d_p)^2 T + a_{10} (E_p) (T).$$

A computer programme was developed to simulate gas exchange in three type of packages, viz. permeable film, impermeable and permeable film with perforation. A lab experiment was performed on broccoli and strawberries to verify the model predictions.

Beaudry *et al.* (1992) reported that the steady state O_2 partial pressures in packages containing same weight of perishables decreased as temperature increased, and used this steady state O_2 and CO_2 partial pressures to calculate rates of O_2 uptake, CO_2 production and respiratory quotient (RQ) and derived following equation for film permeability:

$$\ln (P_i) = Ea/RT + \ln (A)$$

Where, P_i is permeability of the film to gas; Ea activation energy; R gas constant (8.314 j/mol/ K^0). The slope of the fitted line was Ea/R . Increasing the weight of the fruit in the package caused a decrease in steady state O_2 at each temperatures. As the temperatures increased, steady state O_2 tended to decrease for a given package fruit weight.

Cameron *et al.* (1994) developed a mathematical model to characterize interaction of O_2 uptake, steady state O_2 partial pressures in MAP and film permeability to oxygen in fruits held between 0 and 25°C. The O_2 uptake in $RO_2^{\max,T}$ and $\{O_2\}_{pkg}$ at which O_2 uptake was half maximal ($K_{1/2}^T$) were both exponentially related to temperatures. The activation energy of O_2 uptake was less at lower in package O_2 concentration and temperature. The predicted activation energy for permeation of O_2 through the film required to maintain optimum in package O_2 level across range of temperatures between 0 to 25°C was 60 $kJ.mol^{-1}$. The results have been discussed in relation to the risk of temperature abuse during handling and marketing of MA packaged fruits.

Mathematical procedures for predicting steady state O_2 concentration for a range of packaging conditions for MAP of tomatoes were developed and tested by Gong & Corey (1994). The relationship between O_2 consumption rate and O_2 concentration was determined. The fitted function was then used in conjunction with the input variables film permeability to O_2 , film surface area and fruit weight in packages to develop an equation to predict steady state O_2 concentration for different packaging ratios and film permeabilities. The prediction curve showing steady state O_2 closely resembled best fit curves of experimental data. Increasing temperature from 20 to 28°C had little effect on in package O_2 concentration but decreasing temperature from 28 to 10°C led to higher in package O_2 concentration the predictive equation developed can be used to select appropriate films and optimize packaging ratios to achieve desired steady state O_2 concentration for MAP of tomatoes.

Joles *et al.* (1994) studied the respiratory response of red Raspberry to reduced O₂, enhanced CO₂ and temperature. The rates of O₂ uptake, CO₂ production and respiratory quotient (RQ) was calculated using steady state O₂ & CO₂ partial pressures, total package permeability and fruit weight. The O₂ uptake rate decreased with decreasing O₂ partial pressures over the range of partial pressures studied. The Michaelis Menten equation was used to model O₂ uptake as a function of O₂ partial pressure and temperature as:

$$R_{O_2} = \frac{R_{O_2}^{Max} Q_{10}^{T/10} [O_2]_{pkg}}{K_{1/2} + [O_2]_{pkg}}$$

RQ was modelled as a function of O₂ partial pressure and temperature as:

$$RQ = \frac{q \cdot \exp(rT)}{[O_2]_{pkg}} + 1$$

Based on RQ, ethanol production and flavour, it was recommended that raspberries be stored at O₂ levels above 4 kPa at 0°C, 6 kPa at 10°C and 8 kPa at 20°C. The steady state CO₂ partial pressure of 3-17 kPa had little effect on O₂ uptake.

Talasila *et al.* (1995) derived a model which predicted the CO₂ concentration in the packages more closely for a constant surrounding temperature conditions of 15.2°C. Whereas the O₂ concentration were under predicted. For a variable surrounding temperature conditions of 18.6°C for 12 hr, followed by 4.2°C for 48 hrs and then at 18.6°C for 12-20 hrs temperatures and O₂ concentration predicted by model closely agreed with the experimental data. This model could also be used to

predict time required for packaging system to attain the designed optimum conditions. Developed model is valid only for rigid packages.

Fishman *et al.* (1996) developed a mathematical model to study the influence of film perforations on O₂ concentration and relative humidity in a package environment containing mango. The model included equations describing fruit respiration and transpirations as well as permeation of O₂ and water vapour through the perforated film. Closed system experiments revealed a linear dependence of respiration rate on O₂ concentration the model prediction were experimentally verified. It was concluded that perforations had a much more pronounced effect on O₂ concentration than on relative humidity. The model enabled practical predictions for designing modified atmosphere packaging.

Hirata *et al.* (1996) developed theoretical model based on the kinetic molecular theory of gases for designing modified atmosphere packaging with a perforation. Simulated gas flux through perforations was closely approximated to experimental data at three levels of temperatures and two types of initial gas conditions. Changes in the gas compositions in the packages with perforation was fairly predicted using the proposed model. Atmospheric changes in MAP systems with perforations for two kind of fresh produce were also predicted very well by the proposed equations.

Makino *et al.* (1996) proposed a model for fresh produce which included the effect of depressions of respiration caused by CO₂ based on the modified Langmuir absorption theory. The O₂ and CO₂ concentration within the package were periodically measured during storage. Mathematical analysis of a MAP system for

shredded cabbage and broccoli was carried out using the proposed rate equations and basic mass balance. A close agreement of simulated results with experimental data was achieved.

Emond *et al.* (1998) formulated three dimensional mathematical model to predict gas distribution as a function of time inside a perforation generated modified atmosphere bulk package using the principle of diffusion in a gas mixtures. Results showed that package CO₂ concentration increased and O₂ concentration decreased with increasing distance from the perforation.

Laka kul *et al.* (1999) developed a model to study the effect of fruit mass, film permeability to O₂, activation energy of O₂ permeation, temperature and type of film, area and thicknesses on oxygen partial pressure for hermetically packaged apple slices. The data was plotted as dependence of RRO and RQ on in-package oxygen at four temperature viz. 0, 5, 10 & 15°C. Fermentation threshold was determined as O₂ partial pressure below which RQ was estimated to increase above 1.3.

MATERIAL AND METHODS

Investigations were carried out to study the effect of modified atmosphere packaging (MAP) and storage on the keeping quality and physiological parameters of mango cv. Dashehari. Different polymeric films commercially available and having variable thicknesses in combination with different storage environments, were used to select the best suitable polymeric film for extending the shelf-life of mangoes. Films with different levels of perforations were also tried to evaluate the effect on the quality of mangoes. The effect of film wrapping and packaging in different boxes on mechanical damage during transportation was also studied. A mathematical model was also developed to derive a relationship between perforation and levels of oxygen (O_2), carbondioxide (CO_2) and relative humidity (RH or water vapour) inside the package. Details of the materials used and methodology followed in the experiment to achieve the specific objectives have been discussed as under:

3.1 LOCATION AND CLIMATE:

The study was carried out in packaging laboratory and quality analysis laboratory of the Department of Processing and Agricultural Structures and Gas analysis laboratory of School of Energy Studies in Agriculture at P.A.U., Ludhiana. The climate of Ludhiana is sub-tropical which is characterized by

cold and dry winters and hot and humid rainy summer, especially during July to Sept. Ludhiana is situated between 30° – 54' north latitude and 75° – 48' east longitude and 247 meters above mean sea level. The area receives an average rainfall of 712mm (Kumar, 2001).

3.2 MATERIALS:

3.2.1 Preparation of mangoes: The selected mango cv. Dashehari were picked from the orchard of PAU Fruit Research Station, Gangian (Dasua). The mangoes were harvested at mature green but unripe stage as recommended by Srivastava (1967). Mangoes harvested at 'B' and 'C' stage ripen normally and gave best taste and flavour during storage. These were then packed in plastic crates using paper shattering as cushioning material (Raghav, 2000) and transported (Fig.3.1) to packaging laboratory, of the Department of Processing and Agricultural Structures, P.A.U., Ludhiana, covering a distance of 125 kms. in 3 hours. The mangoes were then sorted to remove both damaged, press marked, bruised and over and under size mangoes to have a uniform sample with an average weight ranging between 140-225 gms as recommended by Wardlaw and Leonard (1936). These mangoes had maximum acidity. Mangoes which had started ripening were also removed. These selected lots were then treated with aqueous suspension of 500 ppm Bavistin (Huddar *et al.*, 1995 and Roy and Pal, 1989) and then air dried. The floating mangoes during chemical treatments were also removed to have mangoes with specific gravity greater than 1.00. Such mangoes are assumed to have lowest respiration rate. The mangoes were

then packed in different types of polymeric films (Fig.3.2-3.3 and also see Fig.3.4 showing closed view of non-wrapped mangoes). having different treatments. Mangoes kept in plastic crates were stored under three different storage environments viz., room temperature storage, brick and sand storage (Fig.3.5) and cold storage (Fig.3.6).

3.2.2 Preparation of polymeric films:

Three types of commercially available polymeric films viz. Low density polyethylene (LDPE), high density polyethylene (HDPE) and polyolefin (PO) were used. The thicknesses of the LDPE and HDPE films used were 40, 60, 80 gauge (10, 15, 20 μ) while S-60 (Cryovac, D-955) shrink film (Fig.3.2) had 60 gauge (15 μ) thicknesses. The films were manually perforated with the help of hole puncture of size (special 0000) to have treatments with three levels of perforations (Area bases) viz. 0.26, 0.48, 0.78 percent. The packages of all films prepared had an average effective area of 2 x (16 x 11) = 352 cm² for gas and water vapour exchange.

3.3 EXPERIMENTAL DESIGN:

The whole study was sub-divided into different experiments to achieve the specific objectives.

Experiment 1: To study the effect of packaging in different polymeric films on the keeping quality of mangoes.

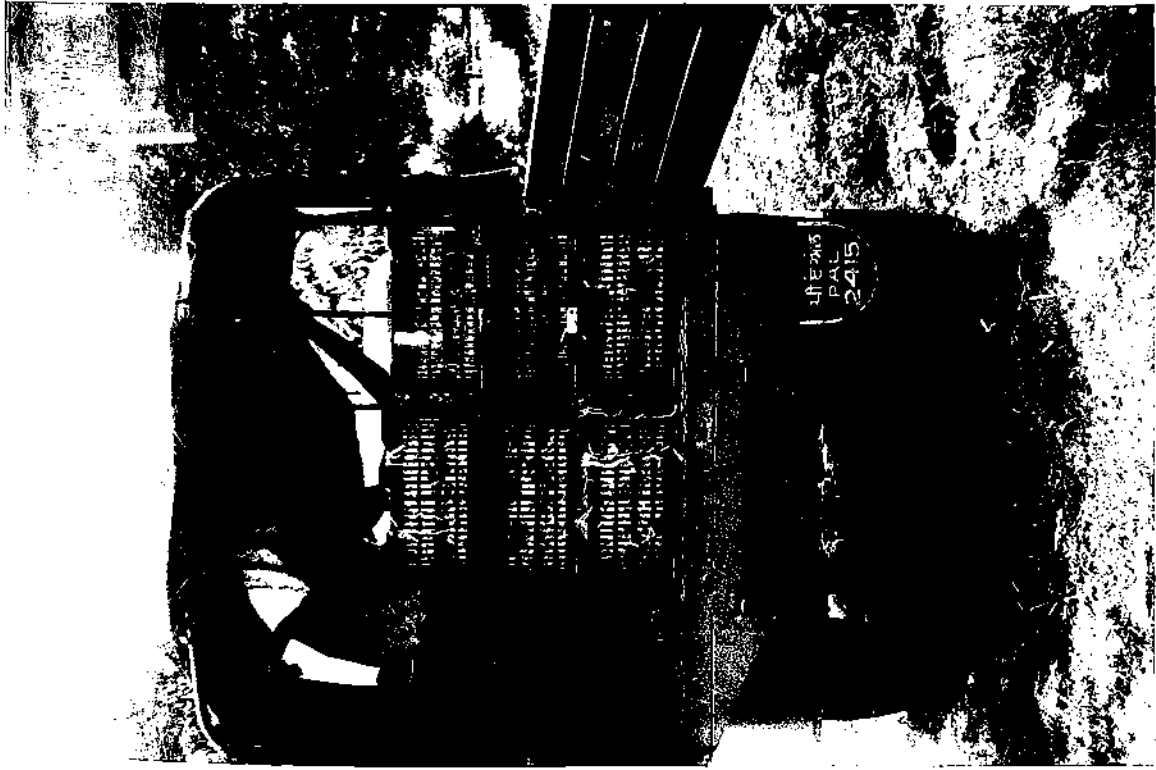


Fig 3.1 A View of transportation of mangoes



Fig 3.2 A view of Shrink wrapping of mangoes



Fig 3.3 A view of non-wrapping and wrapped mangoes under study.



Fig 3.4 Colour development of skin at various stages of ripening



Fig 3.5 A view of brick and sand storage of mangoes

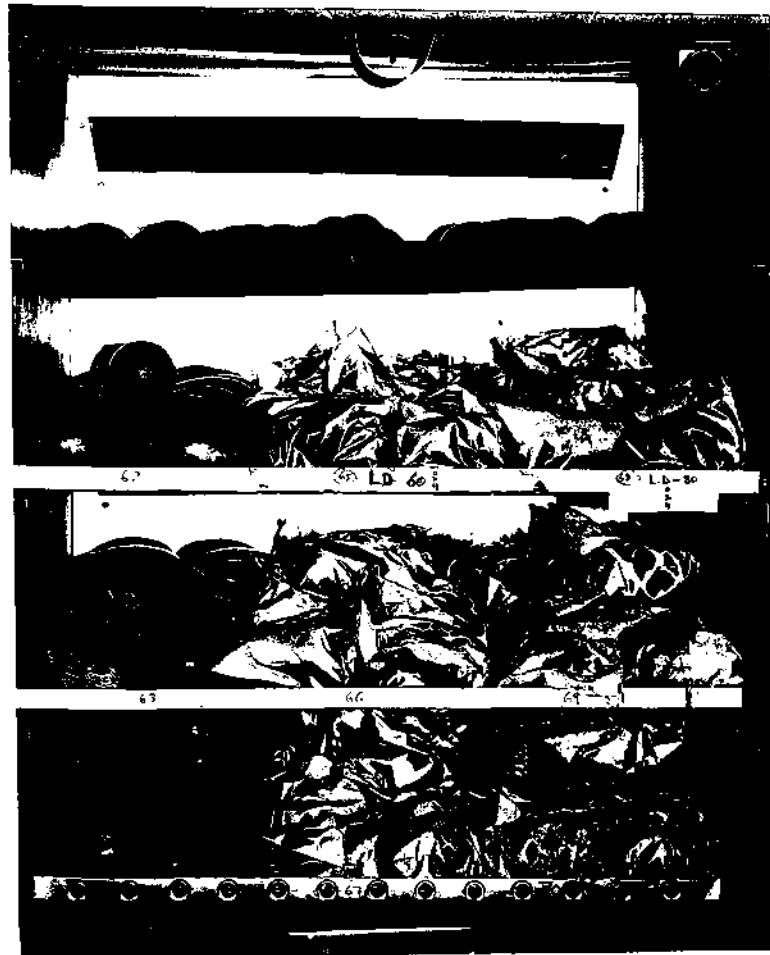


Fig 3.6 A view of cold storage of mangoes

Experiment 2: Estimation of TSS/acid ratio in top three films selected from experiment 1.

Experiment 3: Simulated transportation studies to determine mechanical damage to fruit.

Experiment 4: Measurement of gaseous and water vapour permeability of polymeric films.

Experiment 5: Gas analysis in simulated mango packages to verify the predictions of theoretical model.

Detailed experimental plan is given below:-

| Parameter | Description |
|-----------------------|---|
| EXPERIMENT : 1 | |
| Mango variety | Dashehari |
| Polymeric films | LDPE, HDPE : 40, 60, 80 gauge S-60 (Cryovac – D955) : 60 gauge |
| Treatments | Non-wrapped (Control) Wrapped non-perforated, wrapped perforated (Perforation : 0.26, 0.48, 0.78 percent) |
| Storage Environment | Room temperature storage (RT), Brick and sand storage (B&S) Cold storage (CS) |
| Storage temperature | RT : $30.5 \pm 2.5^{\circ}\text{C}$ B&S : $27 \pm 1^{\circ}\text{C}$ CS : $12.5 \pm 2.5^{\circ}\text{C}$ |
| Storage RH | RT : 80 ± 2.5 percent B&S : >95 percent CS : $85 - 90$ percent |
| Observations recorded | PLW, Colour development of skin (Fig.3.4) Firmness, TSS, pH, decay, shrinkage |
| Storage period (days) | 1,4,7,10,13,16, |

| EXPERIMENT : 2 | |
|-----------------------|---|
| Polymeric films | LD-80, LD-60, S-60 |
| Storage Environment | RT Storage B&S Storage CS storage |
| Treatments | Non-wrapped (Control) Wrapped non-perforated Wrapped perforated (N=2,4) |
| Storage period (days) | 1,4,7,10, |
| Observations recorded | TSS Acidity TSS/acidity ratio |
| EXPERIMENT : 3 | |
| Packaging Box | Wooden Box Corrugated fibre board boxes (CFB) – 5 ply Plastic Crate |
| Treatments | Non-wrapped (Control) Film wrapped (LD-80, LD-60, S-60) |
| Duration | 12, 24, 36, 48, 72 hours |
| Observations Recorded | PLW Mechanical damage (injured and press marks) Transportation Loss (PLW + MD) colour development of skin (Ripening) |
| EXPERIMENT : 4 | |
| Polymeric film | LD-80 |
| Storage environment | RT Storage (30.5±2.5°C, 80±2.5 percent RH) |
| Equipments used | Test jars, gas mixing cylinder Vacuum pump, GLC, Glass syring (1000µL) |
| Parameters recorded | CO ₂ , O ₂ concentration Water vapour concentration (gm) |
| EXPERIMENT : 5 | |
| Polymeric film | LD-80 |
| Storage environment | RT storage |
| Parameters Recorded | Weight, surface area and volume of mangoes weight loss. Head space free volume Gas concentration (O ₂ /CO ₂ , percent), Temperature (°C) RH (percent water vapour concentration) |

3.4 EXPERIMENTAL PROCEDURE:

Detailed experimental procedure in recording various parameters of the study for achieving the specific objectives are explained below:

3.4.1 Measurement of model parameters:

3.4.1.1 Thickness of the film: The thicknesses of all the films used in the studies was measured by using dial gauge calliper having a least count of 0.05mm. Ten layers of films were measured together at four different places to reduce measurement errors.

3.4.1.2 Surface area of mangoes: Slightly ripened (4-5 days old) mangoes of known weight were peeled and cut longitudinally into four pieces. The pulp was removed from the peel to trim each piece to a required thickness. The surface area of each piece was measured by passing through leaf area meter. Five mangoes were used for the studies and average surface area per unit weight of mangoes was computed.

3.4.1.3 Volume of mangoes: It was determined by water displacement method. A volumetric cylinder was filled with water to a pre-determined level. A piece of mango of known weight was submerged into it and final volume was noted. The final volume minus initial volume gave the amount of water displaced which in turn gave the volume of fruit.

3.4.1.4 Volume of simulated package: Volume of simulated package was determined by water displacement method. An empty pet jar was filled with

water and volume of water gave volume of simulated package. Three pet jars were used for the study. The volume of simulated packages used in our studies was 4650 ml.

3.4.1.5 Head space free volume: The void volume in the simulated package is referred as head space free volume. It was determined by subtracting the volume of mangoes from the pet jar. Head space free volume is useful for predicting equilibrium times values and plays an important role in the design of MAP.

3.4.1.6 Measurement of gaseous permeability of the film: The values of permeability coefficients are required in the mathematical model. Although, film permeability studies are conducted under standard test conditions (25°C and 75 percent RH differential or 38°C, 90 percent RH) and these values are converted to suit one's experimental conditions. But it results into errors. It has been found that at RH above 65 percent, the O₂ permeability increases upto 150 times to that at less than 65 percent (Paine and Paine, 1992) that is why the permeability test was conducted at conditions similar to one in actual packages. In actual packages, the outside ambient environment kept on changing (T & RH) which ultimately resulted in a rather variable steady state conditions, i.e. it varied at a shortest period of time. Concentration increase method was used after making proper modifications to suit our conditions (Paine and Paine, 1992). A predetermined mixture of gases, O₂: 1.57 percent; CO₂ : 21.5 percent, N(balance gas) : 76.93 percent was filled in a pet jar similar to one used in MA package simulation studies. The gases were

mixed in a mixing cylinder. The gas mixing technique follows principle of Dalton's Law of partial pressure which states that partial pressure of each component equals its mole fraction times total pressure of the mixture (Kader *et al* 1989). The pet jars were kept under ambient conditions. Due to concentration gradient between internal and external environment, O₂ gas flowed in and CO₂ flowed out till equilibrium is reached. The concentration of each gas was measured by drawing 500µl of gas sample using 1000µL glass syringe and analysing it on GLC. The prediction equations were developed for each gas using curve fit method and concentration of gas could be determined at any time.

3.4.1.7 Water vapour transmission rate of film: Different methods are employed, the world over and each method is modified to suit one's conditions. The pet jars similar to one used in previous studies were used for this study. This was modified version of whole bag method (Moyle, 1998). The RH within the chamber was maintained at 100 percent by keeping a pre-determined amount of water within the jar. The simulated chamber was kept under ambient conditions. Moisture start migrating to the outer environment at a steady rate. The amount of water loss was computed. The data was fitted to a curve to develop a prediction equation which gave the gms of water transmitted per unit time (gm/hr or day).

3.4.1.8 Measurement of respiration rate (RR): A closed system was used (Fig.3.7) to estimate the kinetics of O₂ uptake and CO₂ evolution by mango fruit (Fishman *et al.*, 1996). Fruits of known weight and volume were placed



Fig 3.7 A set up for measurement of respiration rate of mangoes



Fig 3.8 A view of simulated transportation studies.

in pet jars of 4650 ml volume, two each for measurement of respiration rate in terms of O₂ and CO₂ gases. An impermeable cover was mounted tightly on top of each chamber. To prevent gas leakage the top cover was glued and joined to the jar top ring with the help of araldite epoxy-adhesive. Then a cellotape was pasted on the joint to make it further gas tight and provide strength to withstand high pressure developed due to evolution of CO₂ gas. The gas tightness of each jar was tested in preliminary experiments. Each jar was provided with 2 openings 5mm in diameter at the middle of the jar and were plugged with 10mm thick silicon rubber septum. Gas samples (500 μ L) were drawn through the septum using a 1000 μ l gas tight glass syringe. The gas samples were taken at 3-4 hours interval and were analysed using gas liquid chromatograph (GLC) which was equipped with thermal conductivity detector (TCD), two columns: molecular sieve for O₂, porapack for CO₂ and Argon was used as a carrier gas. The GLC gave the gas concentration in terms of areas which were got converted to concentration (percent) of each gas using standard curve. The standard curve was plotted between areas and predetermined concentration of each gas mixed. An equation was developed by curve fitting technique which predicted concentration of a gas at any time. The respiration rate (RR) of the gas was determined by differentiating the prediction equation.

3.4.1.9 MA package simulation: In order to check model predictions experimentally, the MA package was simulated. A pet jar similar to one used in respiration rate studies was employed for the experimentation. The only

exception was that the top impermeable cover was replaced with polymeric films (both perforated and non-perforated). The walls of the simulated packages were practically impermeable to gases. A LDPE film of 80 gauge thickness was stretched over the open side of the package and a ring shaped cover (open in middle) having same dimensions as the package, was clamped over it. The joint between plastic film and package top was lubricated with silicon gel to ensure gas tightness. A cellotape was also pasted over the joint between rubber ring and package wall. The experiment involved three simulated packages: one covered with non-perforated film and other two with film having 2,4 holes each of 1.1mm diameter respectively. The films were perforated before stretching over the pet jar. A hardened steel hole puncture of size special 0000 was used to make holes in the film. A combined temperature and humidity measuring device was placed in the simulated packages along with mango samples. The data was recorded through the transparent film. The simulated packages were kept at room temperature conditions ($30.5 \pm 2.5^\circ\text{C}$, 80 ± 2.5 percent). The gas samples ($500\mu\text{l}$) were drawn through the silicon rubber septum using $1000\mu\text{L}$ gas tight glass syringe and were analysed on GLC. The data was recorded at hourly interval initially upto 5 hours; thereafter at 3-4 hours interval. The temperature and RH within the package were noted at the time of recording gas concentration. The gas concentration as well as temperature and RH were recorded for in package and outside ambient environments. The above experiment was repeated on S-60 film for all the treatments and parameters

except CO₂ gas concentration. The gas concentration obtained from GLC in terms of areas was converted into percent concentration with the help of standardized curve developed for each gas.

3.4.2 Quality parameters:

3.4.2.1 Physiological loss in weight (PLW): Four mangoes of known weight were taken for the studies. These were weighed at 3 days interval. The PLW at each duration was calculated as :

$$\text{PLW (percent) } = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Average PLW for each treatment at each duration was also computed (Raghav, 2000)

3.4.2.2 Colour development of the skin (percent): Colour is one of the important parameters which indicates the stage of ripening. It also affects the commercial value of the product. The basic purpose was to get an idea of comparative change in colour in different treatments. The criteria fixed was that the moment 50 percent area of the fruit turned from light green to light yellow (Fig.3.3-3.4), it was declared as ripened (Rameshwar *et al.*, 1979a). Some mangoes showed an erratic trend.

3.4.2.3 Firmness: A representative sample of 3 mangoes was taken to measure fruit skin firmness (kg) with the help of fruits penetrometer. Firmness was recorded at the middle part of the mango and on both sides (180°) to get an average value for each fruit.

3.4.2.4 Total soluble solids (TSS): TSS gives rough estimate of sugars present in the fruit. A representative sample of three mangoes was taken and juice extracted by piercing and pressing the mango. About 2-3 drops of juice were taken on the prism of refractrometer to record TSS (°Brix).

3.4.2.5 pH: A representative sample of 3 mangoes was taken and the pulp was mixed together and tested for pH with the help of pH meter. The pH meter was calibrated against standardized solution of pH=4. The correction corresponding to ambient temperature setting was also applied.

3.4.2.6 Decay (percent): Fruit decay was measured in terms of percentage rotting. Two samples of 15 mangoes each were kept for the studies and observed for percent rotting at each interval of time (Shrinkage was assumed to be zero)

3.4.2.7 Shrinkage (percent): The above lot of mangoes were also observed for percent shrinkage on weight basis. Here rotting was assumed to be zero.

3.4.2.8 Acidity: A representative sample of 3 mangoes was taken and juice extracted. About 5ml of this juice was taken and titrated against N/10 NaOH solution with phenolphthaleine as indicator and pink colour as end point (Ranganna, 1991). The volume of NaOH used was recorded and acidity was computed as follows:

$$\text{Acidity (gm of anhydrous Malic acid)} = \frac{0.0067 \cdot X \cdot 100}{Y}$$

where,

x : ml of N/10 NaOH used.

Y : ml of sample taken for titration

3.4.2.9 TSS/acidity Ratio: Dividing TSS with acidity values gave TSS/acidity ratio

3.4.3 Transportation loss:

The basic purpose of simulated transportation studies was to observe the individual affect of film wrapping and packaging boxes or combination on the mechanical damage to the fruit. A sample of 45-50 mangoes were wrapped in three polymeric films viz LD-80, LD-60, S-60 etc and kept in three packages viz wooden box, corrugated fibre board boxes (CFB) and plastic crates. Non-wrapped mangoes kept in these packages were taken as control. These boxes were placed on the floor of vibration table (Fig.3.8) for simulated transportation studies. A resonance frequency of 60Hz was selected which produced maximum vibration to the fruits (Raghav 2000). The parameters like physiological loss in weight. (PLW) and mechanical damage (injured, press marked, bruised) were recorded. From these, transportation loss was computed by adding PLW and mechanical damage. The colour development of skin was measured to determine amount (percent) of ripening started. The duration selected for recording different parameters, were 12,24,36,48 and 72 hours.

3.5 STATISTICAL ANALYSIS:

The data observed from various experiments was analysed in terms of effect of film wrapping, perforations, type and thickness of films, type of storage environment and duration of storage on the keeping quality of Dashehari mangoes. The duration selected for statistical analysis were 10,16,19 22nd day of storage. Top three films viz. LD-80, LD-60, S-60 were short listed for the analysis. The parameters studied were PLW, firmness, TSS, pH, decay and TSS/acidity ratio. In addition, statistical analysis was also conducted to see the effect of different films, packaging boxes and durations (12,24,36,48 and 72 hrs) on the transportation loss. The statistical analysis of the data was done by employing randomized block design (RBD) as well as factorial experiment in RBD using CPCS1 computer programme package (Cheema and Singh, 1990). In each treatment, three replications were taken to test the significance of various parameters under study. Means were computed and tested at 5 percent level of critical difference to arrive at the best results of the treatments.

3.6 MODEL DEVELOPMENT AND PARAMETERIZATION:

Two processes contribute to the change in amount (Q) of a gas inside a package containing fruit: physical activity i.e., respiration resulting in O_2 consumption, CO_2 evolution and transpiration, emitting water vapours with a total rate f and permeation of gases through the packaging film with a rate F :

$$\frac{dQ}{dt} = f + F \quad \dots(1)$$

The amount of gas is usually represented by product of partial concentration of gas and head space free volume (V).

$$Q = V.C.$$

The level of water vapours is represented by relative humidity (RH) which may be approximated as C_w :

$$C_w = \frac{H \cdot p_{sat}}{RT} = \alpha \cdot H \quad \dots(2)$$

Where,

$$\alpha = \frac{p_{sat}}{RT}$$

is water vapour concentration under saturation vapour pressure which depends upon temperature and is non-dimensional. Since H has been taken as per cent. So dimensions of C_w are same as that of H. The H is the main variable to be measured and is used in the calculations.

Gas transfer through a polymeric film:

The total permeation flow through a macroscopically homogeneous film is defined as flux J, the gas quantity which crosses a unit area of the film, multiplied by film area S:

$$F = J.S \quad \dots (3)$$

Now if the film is perforated, the perforations represent an alternative route for gas transport which is parallel to the barrier formed by plastic material. In such a case total flow is

$$F = J.S + J_h.S_h \quad \dots(4)$$

Where, S_h is total area of the holes; J_h is flux of gas through unit area of the hole. The steady state diffusion flux of a gas through a non-perforated film obeys the following equation (Cussler, 1984).

$$J = \frac{-P(C - C_A)}{L} \quad \dots(5)$$

Where, C & C_A are concentration of gas inside the package and in the ambient atmosphere respectively; P is permeability coefficient of the film to gas; L is thicknesses of the film.

Emond *et al.* (1991) used term effective permeability instead of diffusivity co-efficient to describe gas exchange through perforations. Hirata *et al.* (1996) used Graham's Law of effusion to describe amount of gas molecules colliding with unit area per unit time of perforation. Kesting and Fritzsche (1993) stated that the diffusion of gas through perforation may be treated as macroscopic diffusion in a cylindrical pathway filled with air and it obeys Fick's Law.

$$J_h = \frac{-D(C-C_A)}{L_h} \quad \dots(6)$$

Where D is diffusion co-efficient of gas in air; L_h is diffusive path length.

Novel (1974) approximated this as: if the distance between perforation is much greater than their radius, then L_h equals length L, of the cylindrical pore, enlarged by the hole radius, R_h , i.e.,

$$L_h = L + R_h \quad \dots(7)$$

We examined different models with different summary for this diffusion problem, which gave similar results. But this model was found to be most suitable. Combining equations (4), (5), (6) and (7) total flux through the polymeric film of area S, with N perforations of radius R_h ($S_h = \pi R_h^2 N$) may be represented as:-

$$F = (C_A - C) \left[\frac{SP}{L} + \frac{S_h \cdot D}{L+R_h} \right] \quad \dots(8)$$

The water vapour flux through the perforated film is represented in a similar way with αH replacing C.:

$$F_w = \alpha(H_A - H) \left[\frac{SP_w}{L} + \frac{S_h \cdot D_w}{L+R_h} \right] \quad \dots(9)$$

Where, H and H_A are RH within and outsider (ambient) the package; D_w is diffusion co-efficient of water vapours in air.

Parameter P, P_w were found experimentally for LDPE film and for S-60 film, these were taken from the published data. The diffusion coefficients D, D_w were known from the literatures.

Respiration:

Respiration rate (RR) is defined as volume of oxygen consumed or CO₂ evolution per unit weight of the fruit in a unit time. Multiplication of RR by fruit weight gives the respiration contribution (f) to changes in gas amount in the head space volume i.e.

$$f = - RRO_2 .W \quad \dots\dots\dots \text{for } O_2$$

$$f = RRCO_2 .W \quad \dots\dots\dots \text{for } CO_2$$

Here -ve sign for O₂ indicates O₂ is consumed, +ve sign in 2nd equation indicates CO₂ evolution. Equations of Michaelis Menten type have been applied (Lee *et al.*, 1991), Cameron *et al.* (1994), Fishman *et al.* (1995), Fishman *et al.* (1996) to describe the respiration rate as a function of concentration in a MA package.

To estimate RR parameters for mango fruit, experiments were performed in a closed system as applied to bell pepper by Fishman *et al.* (1995). Garfinkel and Fegley (1984) found that simpler model with reduced number of parameters would fit the observed data. Rectangular hyperbola was approximated by a linear model with only one parameter for mango by Fishman *et al.* (1996). The linear dependence of mango respiration rate on O₂ concentration has also been reported by Yantarasri *et al.* (1995). All the above studies were conducted at cold storage temperature or at ambient temperatures which were quite low compare to the one prevailing in our region (30.5±2.5 °C). Here RR due to high temperature is so high that about 70 percent of the O₂ is consumed within 4-5 hours and O₂ vacuum is created.

In our case, O₂ concentration at any time was fitted to logarithmic curve and gave the following prediction equation for O₂.

$$C_{O_2} = -1.294 \ln(t) + 6.383 \quad \dots(10)$$

Differential of above equation gave RRo₂

$$RR_{O_2} = \frac{-1.294}{t} \quad \dots(11)$$

Respiration based upon CO₂ evolution was determined by Makino *et al.* (1996): Shredded cabbage, Lee *et al.* (1991) : Strawberries, Yang and Chhinan (1988) : tomatoes. HayaKawa *et al.* (1975) expressed RR as a combination of linear equation containing both O₂ and CO₂ concentration The prediction equation for CO₂ concentration at any time was found to be polynomial in our study:

$$C_{CO_2} = [-0.0002 t^3 + 0.0132 t^2 + 0.3574 t + 0.251] \quad \dots(12)$$

The RR based upon CO₂ evolution is given by:

$$RR_{CO_2} = (-0.0006 t^2 + 0.0264t + 0.3574) \quad \dots(13)$$

Transpiration:

The transpiration flow (f_w) replaces gas flow (f) of equation (1) in case of water vapours. It is defined as amount of water vapours which passes away from total fruit surface per unit time.

$$f_w = \phi_w \cdot s \quad \dots(14)$$

where ϕ_w is water vapour flux from unit area of fruit surface per unit time; s is fruit area. Ben-yehoshua *et al.* (1985) and Fishman *et al.* (1996) used Fick's Law to describe the flux of water vapour through unit area of fruit surface to

study citrus fruit resistance to water vapour transport. Hence ϕ_w is proportional to the difference in RH of fruit internal atmosphere and RH of atmosphere in the package.

$$\phi_w = \rho\alpha (H_f - H) \quad \dots(15)$$

where H_f & H are RH of fruit internal atmosphere and atmosphere in the package respectively; ρ is permeance of fruit surface to water vapour (definition given by Donhowe and Fennema (1994); $\sigma = 1/\rho$ is resistance of fruit surface to water vapour transport often used for describing water vapour flux. Transpiration resistance (σ) of mango fruit was estimated according to method described by Ben-yehoshua *et al.* (1985) using weight loss of 10 mangoes in open air and mean resistance was computed.

Equations of gas exchange in MA package:

Combining equations (1), (8) and (11) gives an equation describing dynamics of O_2 in the MA package.

$$\frac{dC_{O_2}}{dt} = \left[\frac{-1.294}{t} \right] + \frac{[(C_A - C) \left(\frac{SP_{O_2}}{L} + \frac{S_h \cdot D_{O_2}}{L + R_h} \right)]}{V} \quad \dots(16)$$

Combining equation (1), (8) and (13) gives an equation describing dynamics of CO_2 in the MA package.

$$\frac{dC_{CO_2}}{dt} = \frac{[-0.0006t^2 + 0.0264t + 0.3574] + [C_A - C] [SP_{CO_2}/L + D_{CO_2} S_h/L + R_h]}{V} \quad \dots (17)$$

Combining equation (1), (9), (14) and (15) gives an equation describing dynamics of water vapour in MA package.

$$\frac{dH}{dt} = \frac{s\rho}{V} [H_f - H] - [H - H_A] \frac{[\frac{SP_w}{L} + \frac{S_h D_w}{L+R_h}]}{V} \dots\dots\dots (18)$$

Steady state solutions of equations (16), (17) and (18) (denoted by super script *) are obtained by equating the rate to zero, we get

$$C^* (\text{oxygen}) = C_A - \frac{1.294}{[\frac{SP}{L} + \frac{S_h D}{L+R_h}] \frac{t^*}{V}} \dots\dots\dots (19)$$

$$C^* (\text{carbon dioxide}) = C_A - \frac{[-0.0006t^{*2} - 0.0264 t^* - 0.3574]}{[\frac{SP}{L} + \frac{S_h D}{L+R_h}] \frac{t^*}{V}} \dots\dots\dots (20)$$

$$H^* (\text{Water vapour}) = \frac{[s\rho H_f + (\frac{SP_w}{L} + \frac{S_h D_w}{L + R_h}) HA]}{[s\rho + \frac{SP_w}{L} + \frac{S_h D_w}{L + R_h}]} \dots\dots\dots (21)$$

The variation of C* with t in equations (19) and (20) indicates that concentration of gas within the simulated package changes with time, as the change in outside environment temperature causes change in RR of fruit as well as permeability of the film, the combined effect of both of these gives the gas concentration (O₂/CO₂) within the package.

The general solutions of linear differential equations (16), (17) and (18) subject to initial conditions of ambient atmosphere i.e. C=C_A and H=H_A at t=0

$$C_{O_2} = \frac{1}{k.t} [-1.294 \ln(t) + C_A (1 + \frac{k.t}{v}) - C_{11}] \dots\dots\dots (22)$$

$$1 + \frac{\dots\dots\dots}{v}$$

$$C_{11} = 14.898$$

$$C_{CO_2} = \frac{1}{k.t} [-0.0002t^3 + 0.0132t^2 + 0.3574t + C_A (1 + \frac{k.t}{v})] \dots\dots\dots (23)$$

$$1 + \frac{\dots\dots\dots}{v}$$

$$H = H^* - (H^* - H_A) \exp (-t/t_w^{**}) \dots\dots\dots (24)$$

Where $k = [\frac{SP}{L} + \frac{S_h D}{L+R_h}]$ for both O_2 and CO_2

The nature of equation describing dynamics of water vapour is exponential in nature, which necessitates to define a parameter called characteristics time (t^{**}). It is the time that is required for a dynamic variable to traverse a fraction $1 - \exp (-1) \approx 0.63$ of the range from initial to steady state value. It is analogous to the “life time” – a parameter used for describing the first order processes of decay in photo and radio-chemistry (Novel, 1974). The characteristics times for water vapours is given by

$$t_w^{**} = \frac{v}{[\frac{sp}{L} + \frac{SP_w}{L} + \frac{S_h D_w}{L+R_h}]} \dots\dots\dots (25)$$

The above equations represents the solutions of (16), (17) and (18) on the following assumptions.

1. Due to high ambient temperature, the RR is very high and steady state is achieved in a very short time, i.e. $O_2 \approx 40$ hours; $CO_2 \approx 45$ hours in non-perforated film package. This period is insignificant compared to storage

period of over 500 hours under actual storage conditions. Thus fruit remains at steady state for 90 per cent of the storage time. The permeation flow depends upon the gradient between gas concentration within package and outside the package. At steady state RR is at lowest level and hence permeation flow is maximum at steady state. Furthermore, in perforated package, about 97-98 per cent of gas exchange took place through perforation; leaving 2-3 per cent flow through the film and steady state is achieved within no time i.e., O₂: 1-2 hour; CO₂: 5-7 hours. Keeping in view the above facts, the permeation flow F is taken as independent of time and have values corresponding to steady state. This resulted in a rather simpler model for describing the dynamics of gas exchange.

2. The RH fruit internal atmosphere was considered to be 100 per cent. This parameter depends on solute content of the fruit and is slightly less than 100 per cent (Patterson *et al.*, 1993).
3. The coefficient of the equations are constants with time. For climacteric fruits like mango, these parameter are known to change with time. Nevertheless, the above equation provides good approximation when climacteric changes are slower than characteristics times of the system so that coefficients may be considered constant within the time required to reach steady state.

RESULTS AND DISCUSSION

The present study was undertaken on modified atmosphere packaging of mangoes cv. Dashehari. The mangoes were packed in three different types of films having variable thicknesses viz. low density polyethylene (LDPE: 40, 60, 80 gauze), high density polyethylene (HDPE: 40, 60, 80 gauze) and shrink film (S-60: D-955, 60 gauze). The fruits, packed in these films were stored in three different environments viz. room temperatures storage (RT), brick and sand storage (B&S) and cold storage (CS). Various physiological and quality parameters like PLW, firmness, TSS, decay (rotting), pH value and colour development of the skin were recorded at 3 days interval. The mangoes were stored until these were completely spoiled. Taking into consideration all the parameters, top three films were short-listed and TSS/acid ratio of mangoes stored in these films, were carried out, to determine the best film for extending the shelf life of mangoes to optimum level. Mangoes packed in these films and kept in three different packaging boxes viz. wooden box, CFB box and plastic crates, were subjected to simulated transportation studies, to determine the effect of film and packaging box together on mechanical damage to fruits. A theoretical model was also developed to predict O₂, CO₂ concentration as well as relative humidity within the package. An experiment was conducted on simulated packages to verify the model predictions. The experimental results were also statistically analysed using RBD and FRBD technique by using CPCS1 computer programme package

(Cheema & Singh). The results of different experiments have been discussed as under:

- Lab measurement of film thickness
- Storage studies
- Simulated transportation studies
- Mathematical modelling of package environment

4.1 Lab Measurement of Film Thickness:

A perusal of the Table 4.1 shows that there is a great degree of disagreement between lab measurement of film thicknesses and the specifications of the supplier,

Table 4.1 Variation in thickness of commercially available polymeric films

| Type of film | Supplier's claim | | Lab. Measurement | | Variation (%) |
|--------------|------------------|--------|------------------|--------|---------------|
| | gauge | mm | gauge | mm | |
| LDPE | 40 | 0.0100 | 72.95 | 0.0175 | 82.38 |
| | 60 | 0.0152 | 86.88 | 0.0221 | 44.80 |
| | 80 | 0.0203 | 121.8 | 0.0309 | 52.25 |
| | | | | | (59.81). |
| HDPE | 40 | 0.0100 | 54.30 | 0.0138 | 35.75 |
| | 60 | 0.0152 | 65.36 | 0.0166 | 8.93 |
| | 80 | 0.0203 | 79.54 | 0.0202 | 0.55 |
| | | | | | (15.08). |
| S-60 | 60 | 0.0152 | 60 | 0.0152 | 0.00 |

particularly in LDPE films. The average variations were very high in LDPE (59.81 percent) as compared with HDPE (15.08%). HDPE films with the exception of 40 gauge film having 35.75 percent variations, has more or less complete unanimity with the standards. In LDPE, these variations were highest in 40 gauge film (82.38

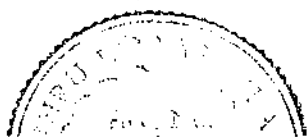
percent) while in other two films, the variations were around 50 percent. The S-60 film completely conformed to standard specifications. All these results are in agreement with the findings of Kumar (2001). Although film thickness effects the gas (GTR) and water vapour transmission rate (WVTR) and various quality parameters especially PLW, yet it is of lesser importance than type of film (polymer mix), density and degree of plasticizer used. It has been found experimentally that two polyethylene films had nearly identical transmission rates, although one film is 64 percent thicker than the other (Moyle *et al.* 1998) which could have reasons other than film thickness. Since gaseous transmission rates could be due to gas solubility on the film surface which creates restrictions to the gas transport through the film. So relative importance of film thickness is not yet clear.

4.2 Storage Studies:

Quality parameters observed during storage studies were PLW, firmness, TSS, decay, shrinkage, colour development of the skin, pH and TSS/acid ratio. These are discussed as under:

4.2.1 Physiological Loss in Weight (PLW):

The average values of PLW in different treatments of all films under different storage environments are given in Table 4.2-4.4 and the trends of change in PLW in top three films are shown in Fig.4.1-4.3. It is clear from Fig.4.1 that PLW increased at a steady rate with the duration of storage and rate of loss increased with the increase in level of perforations with least PLW in non-perforated films (T_0). The control (T) non-wrapped fruits on the other hand, had high rate of PLW compared to wrapped. This is due to high moisture loss caused by high rate of transpiration and



respiration through un-interrupted atmospheric column and under higher temperature and lower relative humidity in comparison to wrapped fruits (Singh and Singh, 1992). Reddy and Raju (1988) stated that lower PLW in wrapped mangoes could be due to lower moisture loss and decreased respiration rate. Gonzalez *et al.* (1997) reported that plastic covering plays an important role in preventing dehydration by creating a saturated micro-atmosphere around the fruit. Mangoes stored in RT suffered more pronounced loss of weight and these losses were more severe as the level of perforation increased.

Thus, under high temperature conditions like the one prevailing in our region, lowest level of perforations will aid in reducing PLW. Again it is apparent from Table 4.5 that rate of PLW decreased with the increase in the thickness of the film irrespective of their level of perforations and type of film. The rate of PLW was lower in HDPE as compared to LDPE and S-60 at all film thicknesses and corresponding treatments. These results are in agreement with the observation of Paine and Paine (1992). Now if all the films are taken together then rate of PLW was found to be 1.88, 0.29 and 1.02 per cent in control, wrapped non-perforated and perforated respectively, indicating film wrapping in general resulted in reduction in PLW.

Similar trends were found in mangoes kept in B&S store (Fig.4.2) and cold stores (Fig.4.3). However, the rate of loss was quite low in all contemporary treatments as compared to RT storage. The rate of loss was 1.88, 0.86 and 0.80 in control (T) treatment of three stores respectively. The losses in non-perforated (T_0) and perforated (T_1 - T_3) treatments were 0.29, 0.19, 0.06 per cent and 1.02, 0.49 and 0.20 in respective stores. This implies that non-perforated treatments in cold storage

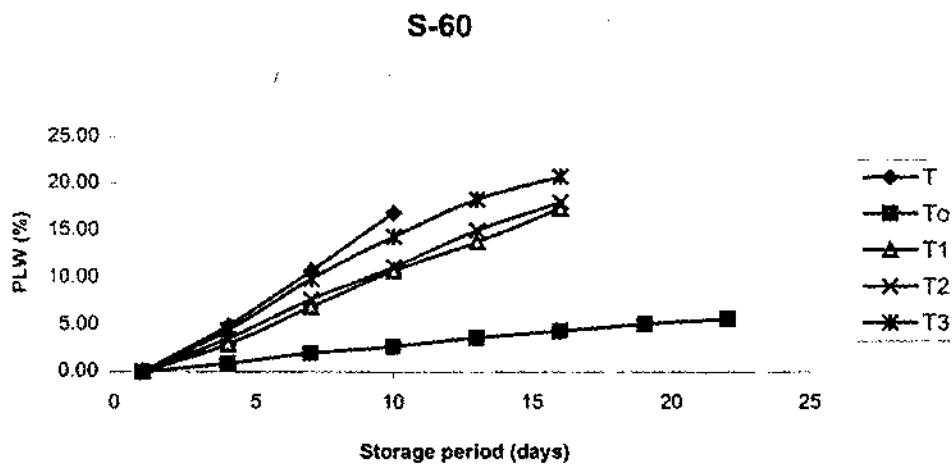
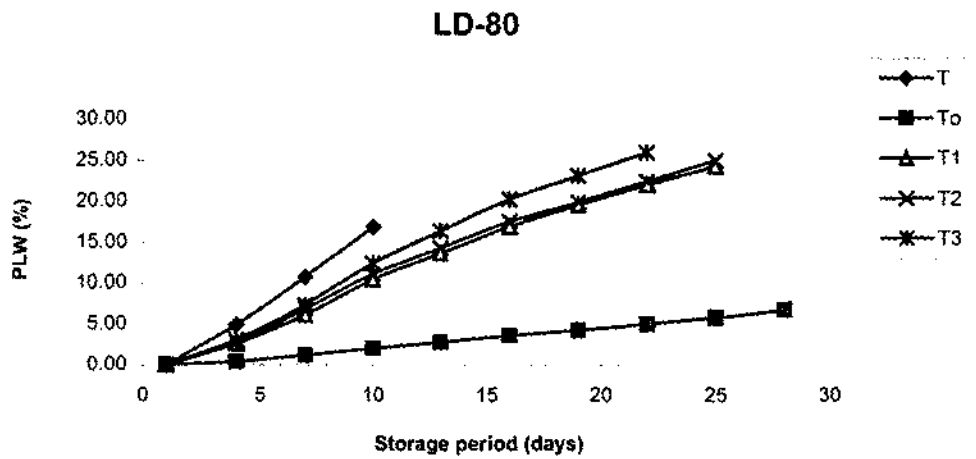
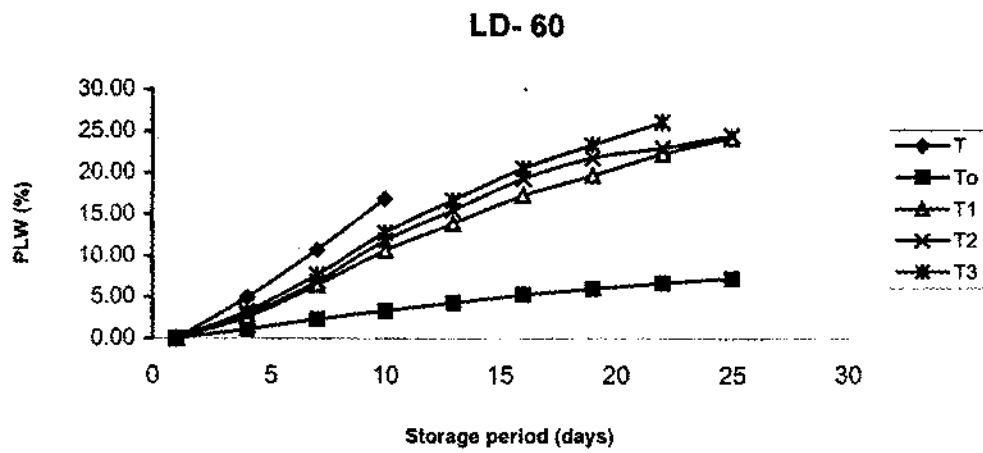
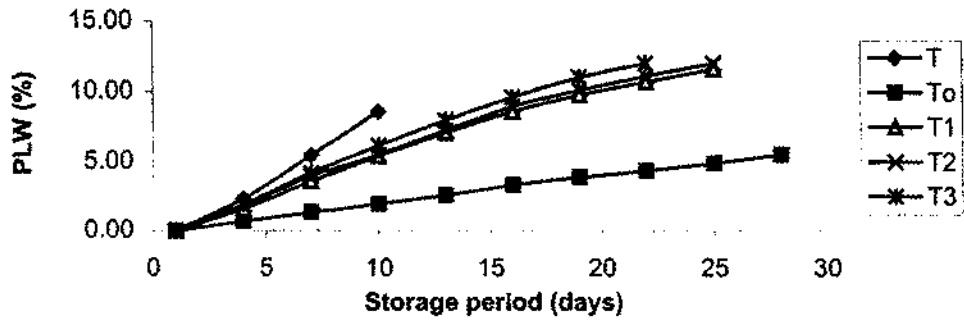
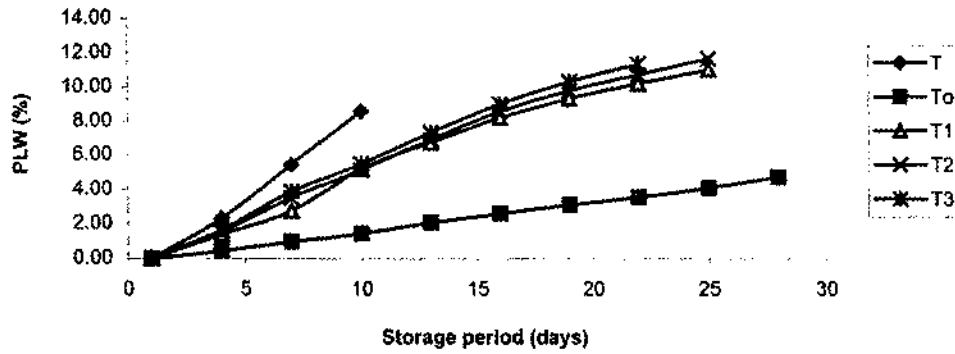


Fig 4.1 PLW under RT storage conditions

LD-60



LD-80



S-60

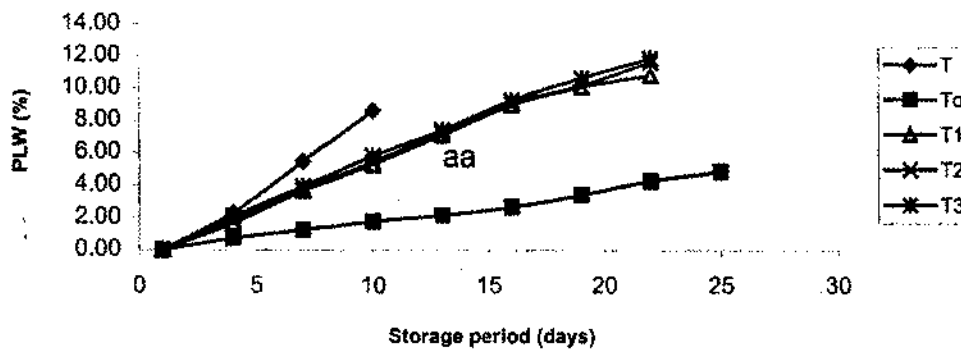


Fig 4.2 PLW under B&S storage conditions

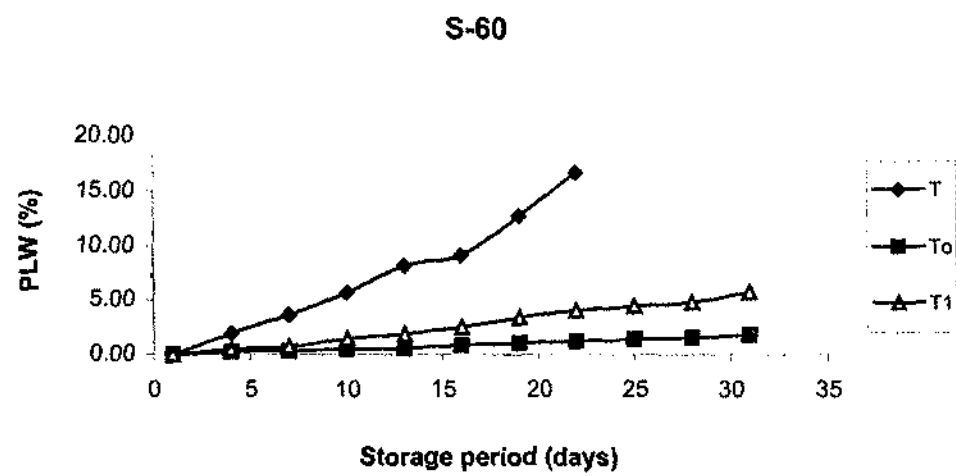
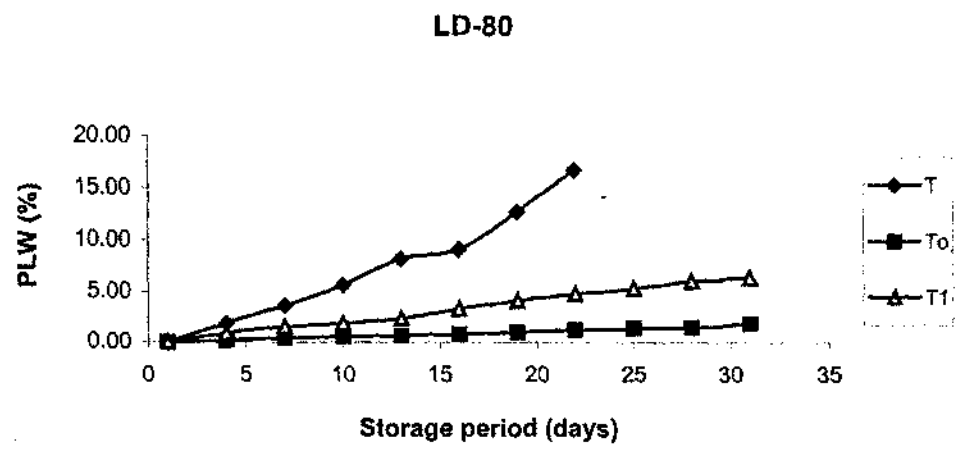
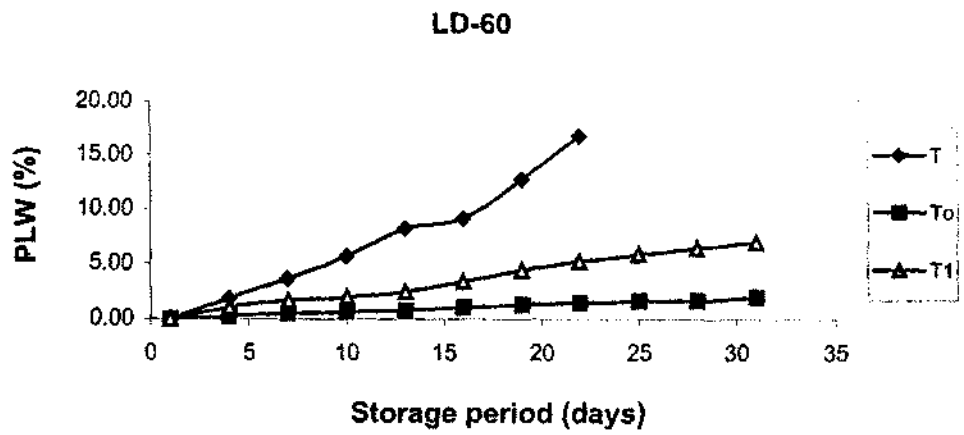


Fig 4.3 PLW under cold storage conditions

Table 4.2 Average values of PLW (%) in different films under room temperature storage conditions

| Duration (days) | Control | Different treatments in films | | | | | | | | | | | |
|--------------------|---------|-------------------------------|-------|-------|-------|--------------|-------|-------|-------|-------------|-------|-------|-------|
| | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 4.93 | 0.81 | 4.40 | 5.18 | 6.17 | 1.55 | 2.66 | 2.98 | 3.26 | 0.90 | 2.92 | 3.55 | 4.43 |
| 7 | 10.74 | 2.03 | 7.30 | 8.48 | 10.20 | 3.12 | 6.11 | 6.97 | 7.74 | 1.97 | 6.91 | 7.69 | 9.87 |
| 10 | 16.90 | 3.47 | 10.28 | 11.95 | 14.13 | 4.46 | 10.50 | 12.20 | 13.27 | 2.72 | 10.75 | 11.16 | 14.36 |
| 13 | | 4.69 | 12.46 | 14.32 | 16.97 | 5.43 | 14.16 | 15.91 | 17.45 | 3.65 | 13.78 | 15.04 | 18.31 |
| 16 | | 5.84 | 15.22 | 16.90 | 19.97 | 6.43 | 17.60 | 19.54 | 21.72 | 4.36 | 17.36 | 17.99 | 20.76 |
| 19 | | 6.74 | 18.61 | 19.94 | 23.70 | 7.70 | 20.02 | 22.15 | 24.49 | 5.10 | | | |
| 22 | | 7.82 | 21.99 | 22.31 | 24.79 | 8.91 | 22.55 | 24.12 | 27.70 | 5.70 | | | |
| | | HD-60 | | | | LD-60 | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | |
| 4 | 4.93 | 0.67 | 2.50 | 2.64 | 3.04 | 1.09 | 2.55 | 2.82 | 3.25 | | | | |
| 7 | 10.74 | 1.63 | 6.32 | 6.77 | 7.23 | 2.31 | 6.40 | 6.85 | 7.71 | | | | |
| 10 | 16.90 | 2.81 | 10.53 | 10.98 | 12.20 | 3.34 | 10.65 | 11.88 | 12.82 | | | | |
| 13 | | 3.70 | 13.84 | 14.04 | 15.96 | 4.33 | 13.97 | 15.53 | 16.77 | | | | |
| 16 | | 4.47 | 17.03 | 17.26 | 19.49 | 5.27 | 17.30 | 19.30 | 20.56 | | | | |
| 19 | | 5.23 | 19.22 | 19.52 | 22.09 | 5.97 | 19.65 | 21.80 | 23.36 | | | | |
| 22 | | 5.72 | 21.64 | 21.93 | 24.51 | 6.64 | 22.24 | 22.97 | 26.09 | | | | |
| 25 | | | | | | 7.24 | 24.18 | 24.46 | | | | | |
| | | HD-80 | | | | LD-80 | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | |
| 4 | 4.93 | 0.41 | 2.57 | 2.41 | 3.11 | 0.45 | 2.62 | 2.77 | 3.11 | | | | |
| 7 | 10.74 | 0.85 | 6.28 | 6.17 | 7.71 | 1.16 | 6.11 | 6.85 | 7.38 | | | | |
| 10 | 16.90 | 1.82 | 10.43 | 11.05 | 12.32 | 2.05 | 10.45 | 11.11 | 12.44 | | | | |
| 13 | | 2.77 | 13.36 | 13.68 | 15.71 | 2.83 | 13.68 | 14.36 | 16.42 | | | | |
| 16 | | 3.35 | 15.94 | 16.59 | 19.26 | 3.63 | 16.93 | 17.56 | 20.28 | | | | |
| 19 | | 4.16 | 17.72 | 18.70 | 21.82 | 4.27 | 19.57 | 19.92 | 23.12 | | | | |
| 22 | | 4.80 | 19.54 | 20.94 | 24.43 | 5.02 | 21.99 | 22.44 | 25.96 | | | | |
| 25 | | 5.37 | | | | 5.82 | 24.27 | 24.97 | | | | | |
| 28 | | | | | | 6.78 | | | | | | | |

Table 4.3 Average values of PLW (%) in different films under brick & sand storage conditions

| Duration (days) | Control | Different treatments in films | | | | | | | | | | | |
|--------------------|---------|-------------------------------|------|------|-------|--------------|-------|-------|-------|-------------|-------|-------|-------|
| | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 2.30 | 0.67 | 1.73 | 1.99 | 2.14 | 0.70 | 1.63 | 1.83 | 2.38 | 0.72 | 1.66 | 1.87 | 2.09 |
| 7 | 5.44 | 1.30 | 3.21 | 3.48 | 4.30 | 1.47 | 3.81 | 3.96 | 4.61 | 1.24 | 3.64 | 3.73 | 3.90 |
| 10 | 8.59 | 1.89 | 4.83 | 5.46 | 6.56 | 2.09 | 5.59 | 5.62 | 6.72 | 1.78 | 5.28 | 5.41 | 5.79 |
| 13 | | 2.60 | 6.39 | 6.91 | 8.10 | 2.79 | 7.30 | 7.29 | 8.62 | 2.17 | 7.09 | 7.21 | 7.38 |
| 16 | | 3.29 | 7.83 | 8.41 | 9.98 | 3.46 | 8.96 | 9.02 | 10.34 | 2.68 | 8.95 | 9.03 | 9.25 |
| 19 | | 3.97 | 9.01 | 9.45 | 11.13 | 4.23 | 10.35 | 10.23 | 11.79 | 3.41 | 10.07 | 10.16 | 10.63 |
| 22 | | 4.57 | 9.91 | 9.91 | 12.24 | 4.88 | 11.30 | 11.31 | 12.90 | 4.27 | 10.81 | 11.62 | 11.85 |
| 25 | | | | | | 5.65 | | | | 4.84 | | | |
| | | HD-60 | | | | LD-60 | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | |
| 4 | 2.30 | 0.64 | 1.66 | 1.83 | 1.81 | 0.67 | 1.57 | 1.80 | 1.90 | | | | |
| 7 | 5.44 | 1.22 | 3.13 | 3.27 | 4.00 | 1.32 | 3.55 | 3.93 | 4.19 | | | | |
| 10 | 8.59 | 1.71 | 4.73 | 5.18 | 6.11 | 1.96 | 5.41 | 5.52 | 6.14 | | | | |
| 13 | | 2.34 | 6.03 | 6.30 | 8.00 | 2.59 | 7.04 | 7.23 | 7.96 | | | | |
| 16 | | 3.01 | 7.46 | 7.83 | 9.67 | 3.33 | 8.56 | 8.94 | 9.61 | | | | |
| 19 | | 3.51 | 8.25 | 8.76 | 11.06 | 3.89 | 9.77 | 10.13 | 11.02 | | | | |
| 22 | | 4.07 | 9.00 | 9.38 | 12.05 | 4.34 | 10.71 | 11.12 | 12.02 | | | | |
| 25 | | 4.67 | | | | 4.90 | 11.63 | 12.03 | | | | | |
| 28 | | | | | | 5.52 | | | | | | | |
| | | HD-80 | | | | LD-80 | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | |
| 4 | 2.30 | 0.45 | 1.30 | 1.45 | 1.72 | 0.43 | 1.38 | 1.54 | 1.65 | | | | |
| 7 | 5.44 | 0.88 | 2.83 | 3.18 | 3.86 | 0.96 | 2.74 | 3.49 | 3.85 | | | | |
| 10 | 8.59 | 1.35 | 4.10 | 4.48 | 5.85 | 1.46 | 5.18 | 5.16 | 5.49 | | | | |
| 13 | | 1.80 | 5.38 | 6.03 | 7.36 | 2.05 | 6.73 | 6.91 | 7.31 | | | | |
| 16 | | 2.35 | 6.59 | 7.40 | 9.20 | 2.59 | 8.18 | 8.57 | 9.00 | | | | |
| 19 | | 2.65 | 7.61 | 8.45 | 10.68 | 3.08 | 9.31 | 9.78 | 10.30 | | | | |
| 22 | | 3.33 | 8.37 | 9.24 | 11.50 | 3.52 | 10.19 | 10.71 | 11.34 | | | | |
| 25 | | 3.81 | | | | 4.07 | 11.00 | 11.65 | | | | | |
| 28 | | | | | | 4.70 | | | | | | | |

Table 4.4 Average values of PLW (%) in different films under cold storage conditions

| Duration (days) | Control T | Different treatments in films | | | | | |
|--------------------|--------------|-------------------------------|------|-------|------|------|------|
| | | HD-40 | | LD-40 | | S-60 | |
| | | T0 | T1 | T0 | T1 | T0 | T1 |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 1.91 | 0.23 | 1.01 | 0.18 | 1.22 | 0.23 | 0.44 |
| 7 | 3.63 | 0.33 | 1.43 | 0.46 | 1.87 | 0.32 | 0.71 |
| 10 | 5.65 | 0.74 | 1.92 | 0.49 | 2.31 | 0.48 | 1.43 |
| 13 | 8.20 | 0.83 | 2.34 | 0.73 | 2.87 | 0.57 | 1.84 |
| 16 | 9.14 | 0.93 | 2.99 | 1.03 | 3.75 | 0.83 | 2.48 |
| 19 | 12.75 | 1.05 | 3.86 | 1.38 | 4.85 | 1.03 | 3.36 |
| 22 | 16.77 | 1.31 | 4.61 | 1.55 | 5.63 | 1.22 | 4.04 |
| 25 | | 1.43 | 5.03 | 1.70 | 6.17 | 1.37 | 4.43 |
| 28 | | 1.57 | 5.62 | 1.88 | 6.59 | 1.52 | 4.78 |
| 31 | | 1.88 | 6.17 | 2.06 | 7.27 | 1.75 | 5.72 |
| | | HD-60 | | LD-60 | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| 4 | 1.91 | 0.17 | 0.90 | 0.22 | 1.06 | | |
| 7 | 3.63 | 0.31 | 1.36 | 0.50 | 1.69 | | |
| 10 | 5.65 | 0.41 | 1.58 | 0.62 | 1.96 | | |
| 13 | 8.20 | 0.54 | 2.05 | 0.79 | 2.49 | | |
| 16 | 9.14 | 0.80 | 2.76 | 1.04 | 3.37 | | |
| 19 | 12.75 | 1.00 | 3.55 | 1.30 | 4.42 | | |
| 22 | 16.77 | 1.17 | 4.18 | 1.48 | 5.21 | | |
| 25 | | 1.33 | 4.64 | 1.63 | 5.83 | | |
| 28 | | 1.42 | 5.09 | 1.69 | 6.44 | | |
| 31 | | 1.71 | 5.51 | 1.99 | 6.98 | | |
| | | HD-80 | | LD-80 | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | |
| 4 | 1.91 | 0.17 | 0.86 | 0.16 | 0.92 | | |
| 7 | 3.63 | 0.31 | 1.27 | 0.40 | 1.53 | | |
| 10 | 5.65 | 0.42 | 1.49 | 0.52 | 1.86 | | |
| 13 | 8.20 | 0.54 | 1.82 | 0.65 | 2.35 | | |
| 16 | 9.14 | 0.77 | 2.54 | 0.78 | 3.33 | | |
| 19 | 12.75 | 0.91 | 3.25 | 1.01 | 4.14 | | |
| 22 | 16.77 | 1.06 | 3.89 | 1.24 | 4.80 | | |
| 25 | | 1.29 | 4.31 | 1.39 | 5.31 | | |
| 28 | | 1.42 | 4.91 | 1.49 | 6.07 | | |
| 31 | | 1.69 | 5.45 | 1.82 | 6.37 | | |

Table 4.5 Rate of weight loss in different films and storage environments

| Type of Store | Type of film | Rate/day | | | | | Average rate | | | Loss reduction | |
|---------------|--------------|---------------------|------------------------|------|------|------|--------------|------|------|----------------|-------|
| | | T | To | T1 | T2 | T3 | T | To | T1-3 | T/To | T/T13 |
| RT | HDPE | 1.88 | 0.36 | 1.00 | 1.01 | 1.13 | 1.88 | 0.29 | 1.02 | 6.5 | 3.51 |
| | | | 0.26 | 0.98 | 0.99 | 1.11 | | | | | |
| | | | 0.21 | 0.89 | 0.95 | 1.11 | | | | | |
| | 0.41 | | 1.03 | 1.10 | 1.26 | | | | | | |
| | 0.29 | | 0.99 | 0.99 | 1.19 | | | | | | |
| | 0.24 | | 0.97 | 0.98 | 1.18 | | | | | | |
| LDPE | 0.26 | 1.09 | 1.12 | 1.30 | | | | | | | |
| B&S | HDPE | 0.86 | 0.21 | 0.45 | 0.45 | 0.56 | 0.86 | 0.19 | 0.49 | 4.53 | 2.57 |
| | | | 0.19 | 0.41 | 0.43 | 0.55 | | | | | |
| | | | 0.15 | 0.38 | 0.42 | 0.52 | | | | | |
| | 0.23 | | 0.51 | 0.51 | 0.59 | | | | | | |
| | 0.20 | | 0.47 | 0.48 | 0.55 | | | | | | |
| | 0.17 | | 0.44 | 0.47 | 0.52 | | | | | | |
| LDPE | 0.19 | 0.49 | 0.53 | 0.54 | | | | | | | |
| CS | HDPE | 0.80 | 0.06 | 0.20 | | | 0.80 | 0.06 | 0.20 | 13.54 | 3.37 |
| | | | 0.06 | 0.18 | | | | | | | |
| | | | 0.05 | 0.18 | | | | | | | |
| | 0.07 | | 0.23 | | | | | | | | |
| | 0.06 | | 0.22 | 0.80 | 0.06 | | | | | | |
| | 0.06 | | 0.21 | | | | | | | | |
| LDPE | 0.06 | 0.18 | 3.27 | | | | | | | | |
| NOTE : | | T : Control | T1 : Perforated(0.26%) | | | | | | | | |
| | | To : Non-perforated | T2 : Perforated(0.48%) | | | | | | | | |
| | | | T3 : Perforated(0.78%) | | | | | | | | |

resulted in 13.54 time reduction in PLW compared with control. On the other hand, RT and B&S storages resulted in reduction of PLW by 4.53-6.50 times. The perforated films resulted in 2.57-3.51 times reduction in rate of PLW irrespective of the type of store. The PLW in top three films (non-perforated) viz. LD-80, LD-60 and S-60 were 6.78, 7.24, 5.70 percent 4.70, 5.52, 4.84 and 1.82, 1.99, 1.75 per cent in RT, B&S and cold storage respectively (Table 4.2-4.4). Identical observations were reported by Batagurki *et al.*(1995), Reddy and Raju (1988), McCollum *et al.* (1992), Singh and Narayana (1995), Mann and Singh (1976), Thomos (1975), Joshi and Roy (1986), Singh and Singh (1992), Sahni and Khurdiya (1989) and Gonzalez *et al.* (1997).

Table 4.6 Statistical analysis of physiological loss in weight of mangoes

| Duration (days) | Treat. combination means | | | Factor means | | | CD (5%) | | | |
|---|--------------------------|------|-------|--------------|-------|-------|------------------|----|------|-------|
| | T | To | T1-3 | FI | Tt | St | Tt | FI | TxFI | St |
| 10 | 12.75 | 2.65 | 8.74 | 7.22 | 2.22 | 10.05 | 2.298 (4.04). | - | - | 1.586 |
| | | 1.76 | 8.31 | 6.67 | 7.95 | 4.86 | | | | |
| | | 2.25 | 8.80 | 7.16 | 8.37 | 9.51 | | | | |
| 15 | | 4.30 | 14.03 | 11.60 | 3.64 | 3.482 | - | - | | |
| | | 3.11 | 13.42 | 10.84 | 12.88 | | | | | |
| | | 3.52 | 13.89 | 11.30 | 13.57 | | | | | 14.89 |
| 19 | | 4.93 | 15.96 | 13.20 | 4.30 | 5.382 | - | - | | |
| | | 3.68 | 15.33 | 12.42 | 14.58 | | | | | 15.41 |
| | | | | | 16.95 | | | | | |
| 22 | | 5.49 | 17.53 | 14.52 | 4.88 | 6.02 | - | - | | |
| | | 4.27 | 17.11 | 13.90 | 16.28 | | | | | 16.81 |
| | | | | | 18.85 | | | | | |
| NOTE: Tt: Treatment(To,T1,T2,T3) St: Store (RT,B&S) FI: Film (LD-60,LD-80,S-60) TtxFI: Interaction | | | | | | | | | | |

4.2.1.1 Statistical Analysis: The results of statistical analysis are shown in Table 4.6. the store means of 10.05 and 4.86 for two non-refrigerated stores indicated that PLW in B&S store was around half as compared to RT store. The film had non-significant effect while treatments had significant effect. The LD-80 film had the lowest film means both in perforated as well as non-perforated treatments during different periods of storage. The CD (5 percent) values for treatments were 2.298, 3.342, 5.382 and 6.02 after 10, 16, 19 and 22 days of storage which implied that effect of treatments increased with the duration of storage. The interaction of film and treatments was non-significant. All these findings were in agreement with the experimental results.

4.2.2 Colour Development of Skin

Colour is one of the parameters which indicate the stage of ripening, but it has to be correlated with bio-chemical constituents of the fruit to find exact stage of ripening. The colour changes in different treatments of all the films and storage environments are presented in Table 4.7-4.8 and the trends of change in top three films are shown in Fig.4.4-4.5.

As seen from Fig.4.4 it is clear that colour change in control fruits is very rapid as it evident from the fact that complete colour change took place between 4-7th day of storage. Wrapped mangoes, on the other hand, had very slow colour change especially in non-perforated treatments. The colour change started on 7th day and was complete after 13th day in perforated and 16th day in non-perforated treatments of HDPE films. This implied that wrapping slowed down colour change and took double the period for colour change than control fruits. The colour change was

directly proportional to level of perforations and inversely proportional to thickness of the film. This was attributed to slow rate of ripening in wrapped fruits (Singh and Narayana, 1995; Miller and Risse, 1988). Rameshwar *et al.* (1979a) reported that changes in amino-acids is closely associated with ripening. The perforated treatments were best in retaining excellent colour (golden yellow) and showed marked superiority of appearance over other treatments. However, in non-perforated film treatments, colour change was not so prominent which could be gauged from the fact that final colour remained very light green to light yellow. In control fruits, on the other hand, some green colour remained as such at the tail side. Similar trends were found in LDPE and S-60 films irrespective of their thicknesses and level of perforations. The LDPE films with no perforations took highest period of 19 days for complete colour change. Similar trends were found in all treatments of B&S store (Fig.4.5) but rate of colour change was marginally slow.

The cold storage treatments gave a contrast picture regarding colour change compared with RT and B&S storage. The colour remained green in all treatments even in control throughout the period of storage irrespective of type and thicknesses of the films. When cold stored mangoes were kept out for few days, even then colour did not change altogether. Joshi and Roy (1986) reported that fruits in cold storage displayed slower rate of fruit ripening than room temperature storage. This might be due to retardation of certain physiological processes particularly respiration rate at low temperature (Subramanyan *et al.* 1972). These findings are in conformity with the observations reported by Saucedo *et al.* (1978), Mukherjee and Srivastava (1979a), Chaplin *et al.* (1982), Garg *et al.* (1971) and Rameshwar *et al.* (1979a).

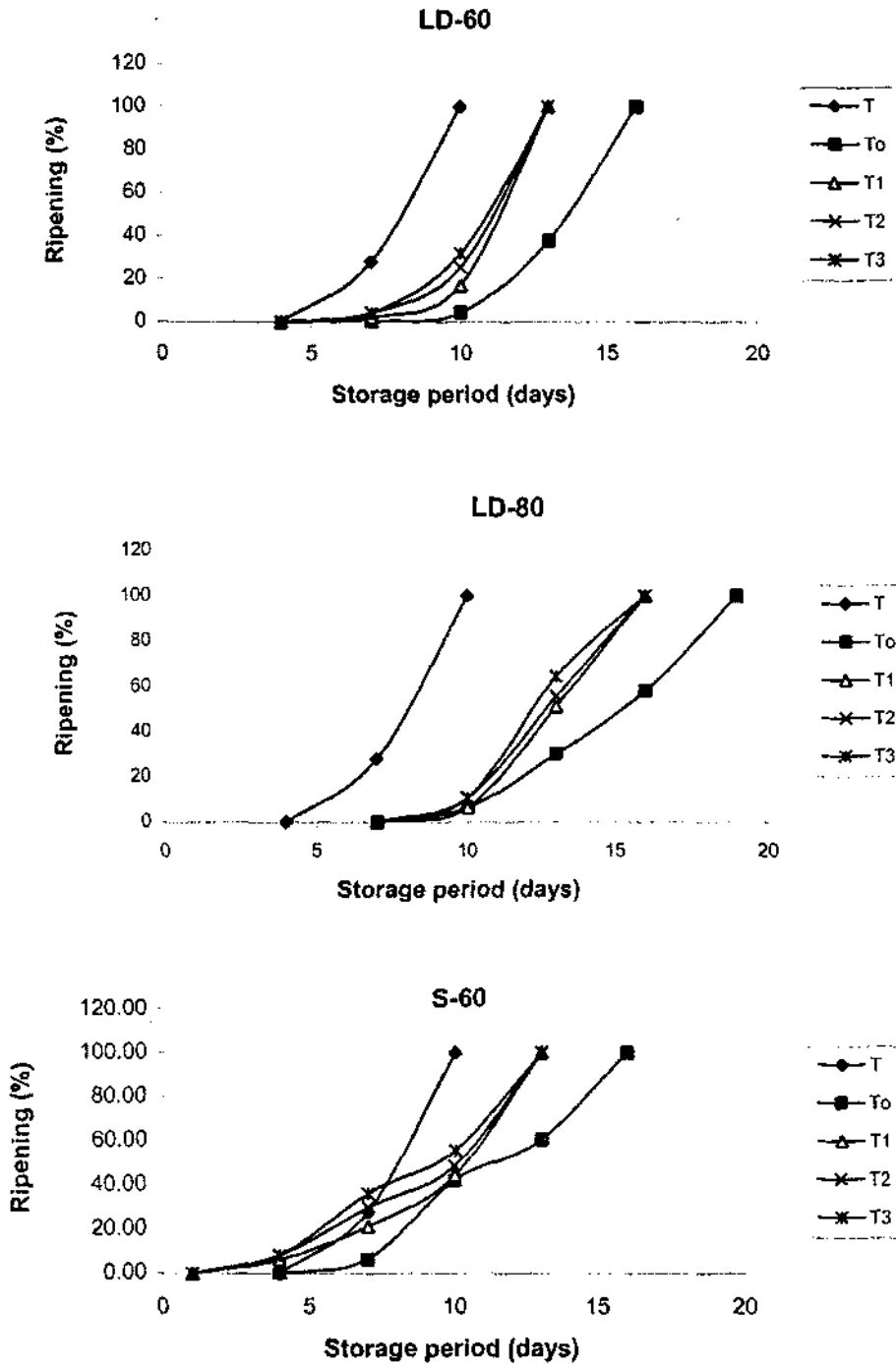


Fig 4.4 Ripening under RT storage conditions

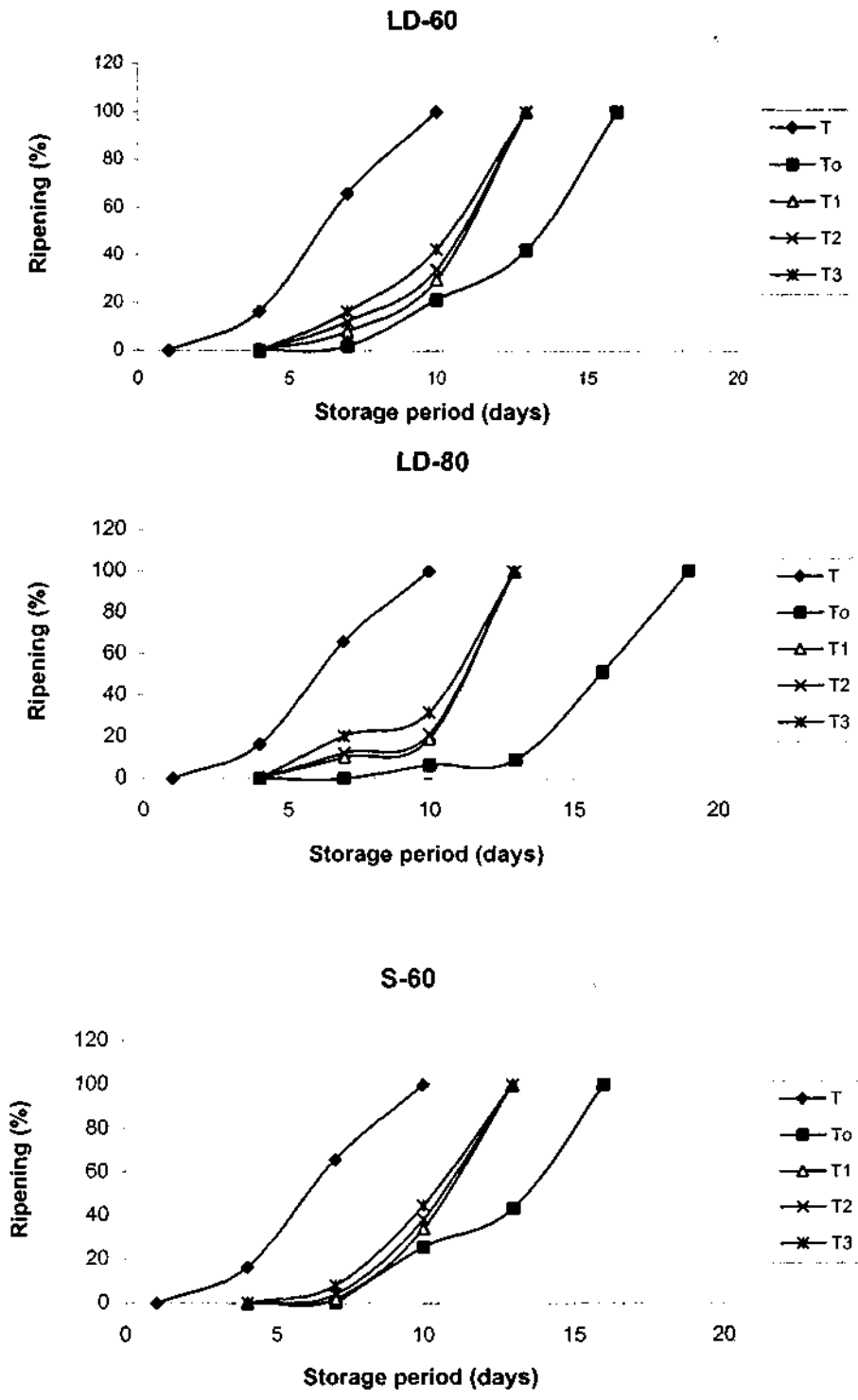


Fig 4.5 Ripening under B&S storage conditions

Table 4.7 Colour development of skin (%) in different films under room temperature storage conditions

| Duration (days) | Control | Different treatments in films | | | | | | | | | | | |
|-----------------|---------|-------------------------------|--------|--------|--------|--------------|--------|--------|--------|-------------|--------|--------|--------|
| | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | 28.00 | - | - | - | - | - | - | - | - | - | 6.12 | 8.16 | 8.16 |
| 7 | 100.00 | 6.12 | 10.20 | 12.24 | 16.33 | 2.04 | 6.12 | 8.16 | 8.16 | 6.38 | 21.28 | 29.79 | 36.17 |
| 10 | | 21.28 | 38.30 | 46.81 | 55.32 | 21.28 | 53.19 | 55.32 | 68.09 | 42.22 | 44.44 | 48.89 | 55.56 |
| 13 | | 82.22 | 100.00 | 100.00 | 100.00 | 66.67 | 100.00 | 100.00 | 100.00 | 60.47 | 100.00 | 100.00 | 100.00 |
| 16 | | 100.00 | | | | 100.00 | | | | 100.00 | | | |
| | | HD-60 | | | | LD-60 | | | | | | | |
| 1 | - | - | - | - | - | - | - | - | - | | | | |
| 4 | 28.00 | - | - | - | - | - | - | - | - | | | | |
| 7 | 100.00 | 4.08 | 4.08 | 4.08 | 6.12 | 0.00 | 2.04 | 4.08 | 4.08 | | | | |
| 10 | | 25.53 | 44.68 | 51.06 | 57.45 | 4.26 | 17.02 | 25.53 | 31.91 | | | | |
| 13 | | 57.16 | 100.00 | 100.00 | 100.00 | 37.78 | 100.00 | 100.00 | 100.00 | | | | |
| 16 | | 100.00 | | | | 100.00 | | | | | | | |
| | | HD-80 | | | | LD-80 | | | | | | | |
| 1 | - | - | - | - | - | - | - | - | - | | | | |
| 4 | 28.00 | - | - | - | - | - | - | - | - | | | | |
| 7 | 100.00 | 2.04 | 8.16 | 12.24 | 14.29 | - | - | - | - | | | | |
| 10 | | 10.64 | 23.40 | 40.43 | 48.94 | 6.38 | 6.38 | 10.64 | 10.64 | | | | |
| 13 | | 51.11 | 100.00 | 100.00 | 100.00 | 30.00 | 51.11 | 55.56 | 64.44 | | | | |
| 16 | | 100.00 | | | | 58.14 | 100.00 | 100.00 | 100.00 | | | | |
| | | | | | | 100.00 | | | | | | | |

Table 4.8 Colour development of skin (%) in different films under brick & sand storage Conditions

| Duration | Control | Different treatments in films | | | | | | | | | | | |
|----------|---------|-------------------------------|--------|--------|--------|--------------|--------|--------|--------|-------------|--------|--------|--------|
| | | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | 16.33 | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | 65.96 | 4.08 | 10.20 | 12.24 | 18.37 | 8.16 | 8.16 | 16.33 | 16.33 | - | 2.04 | 4.08 | 8.16 |
| 10 | 100.00 | 14.89 | 40.43 | 44.68 | 53.19 | 27.66 | 34.04 | 40.43 | 53.19 | 25.53 | 34.04 | 38.30 | 44.68 |
| 13 | | 60.00 | 100.00 | 100.00 | 100.00 | 58.89 | 100.00 | 100.00 | 100.00 | 43.33 | 100.00 | 100.00 | 100.00 |
| 16 | | 100.00 | | | | 100.00 | | | | 100.00 | | | |
| | | HD-60 | | | | LD-60 | | | | | | | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | 16.33 | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | 65.96 | 4.08 | 8.16 | 14.29 | 16.33 | 2.04 | 8.16 | 12.24 | 16.33 | | | | |
| 10 | 100.00 | 17.02 | 42.55 | 44.68 | 61.70 | 21.28 | 29.79 | 34.04 | 42.55 | | | | |
| 13 | | 51.11 | 100.00 | 100.00 | 100.00 | 42.22 | 100.00 | 100.00 | 100.00 | | | | |
| 16 | | 100.00 | | | | 100.00 | | | | | | | |
| | | HD-80 | | | | LD-80 | | | | | | | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | 16.33 | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | 65.96 | 2.04 | 6.12 | 14.29 | 16.33 | - | 10.20 | 12.24 | 20.41 | | | | |
| 10 | 100.00 | 8.51 | 31.91 | 42.55 | 46.81 | 6.38 | 19.15 | 21.28 | 31.91 | | | | |
| 13 | | 46.67 | 100.00 | 100.00 | 100.00 | 8.89 | 100.00 | 100.00 | 100.00 | | | | |
| 16 | | 100.00 | | | | 51.16 | | | | | | | |
| 19 | | | | | | 100.00 | | | | | | | |

4.2.3 Firmness:

The average values of firmness (kg/cm^2) in different treatments of all films and storage environment are given in Table 4.9-4.11 and the trends of change in firmness are shown in Fig.4.6-4.8.

As seen from the Fig.4.6 it is clear that firmness was comparatively low in control fruits compared to film wrapped irrespective of duration of storage and treatments. The decrease in firmness is indicative of start of ripening process. Pressure being indicative of texture of fruit, due to the salubilization of pectic substances caused by activity of esterase and polygalacturonase as supported by findings of Rolz (1972) and Sahni and Khurdiya (1989). Wills *et al.* (1981) stated that reduction in firmness was due to softening of fruits by dissolution of middle lamella. Since the rate of ripening in wrapped fruits was lower than non-wrapped, so was firmness (Chaplin *et al.* 1982). In control fruits, the firmness decreased sharply right from beginning. In HDPE film wrapped fruits on the other hand, the firmness decreased rapidly after 7th day thereafter, it decreased at a steady rate till the end of storage. Non-perforated treatments had generally more firmness than perforated one at all durations especially after 10th day. Initially upto 10 days all treatments had comparable values. In treatments having different level of perforations, no definite trend has been found, but firmness decreased slightly with the level of perforations. This might be due to more availability of O_2 with the level of perforations. Yang and Chinnan (1988) reported that firmness values decreased with increasing O_2 concentrations and decreasing CO_2 concentrations. Changes in O_2 concentrations showed a more pronounced effect than CO_2 concentrations on the firmness of

tomatoes, hence it verified our findings. Singh and Narayana (1995) found that firmness was significantly effected by storage period and not by per cent ventilation and fruits in sealed bags had maximum firmness and were unripe. Similar results had been reported by Chaplin *et al.* (1982). In LDPE films, firmness increased with the thickness of the film. However, the difference was more significant in non-perforated films than perforated where it was only marginal. The LDPE films had generally higher firmness than HDPE films especially at higher gauze thicknesses. The thickness thus played an important role on firmness in LDPE than HDPE films which had erratic trend of firmness. The firmness was very low in perforated treatments of S-60 films. This was due to imperfect shrink wrapping (14.5 percent) on account of high perforation and machine sieve press marks.

Similar trends were found in B&S store (Fig.4.7) as far as comparison between control and wrapped fruits is concerned. However, the firmness was generally higher in B&S store than RT store in all the films and treatments. Again, firmness was more in LDPE than HDPE films during entire period of storage and at all thicknesses especially at higher one. Since actual thicknesses of LDPE films (Lab Tests) was higher than supplier's claim or standard specifications. So higher thicknesses might have played a role in providing more protection to fruits from severe heat than HDPE film fruits. Here in film wrapped mangoes firmness decreased at a more steady rate than at RT store. In S-60 film, unlike in RT store, had higher and comparative values of firmness. There was erratic trend of firmness in perforated treatments of all the films.

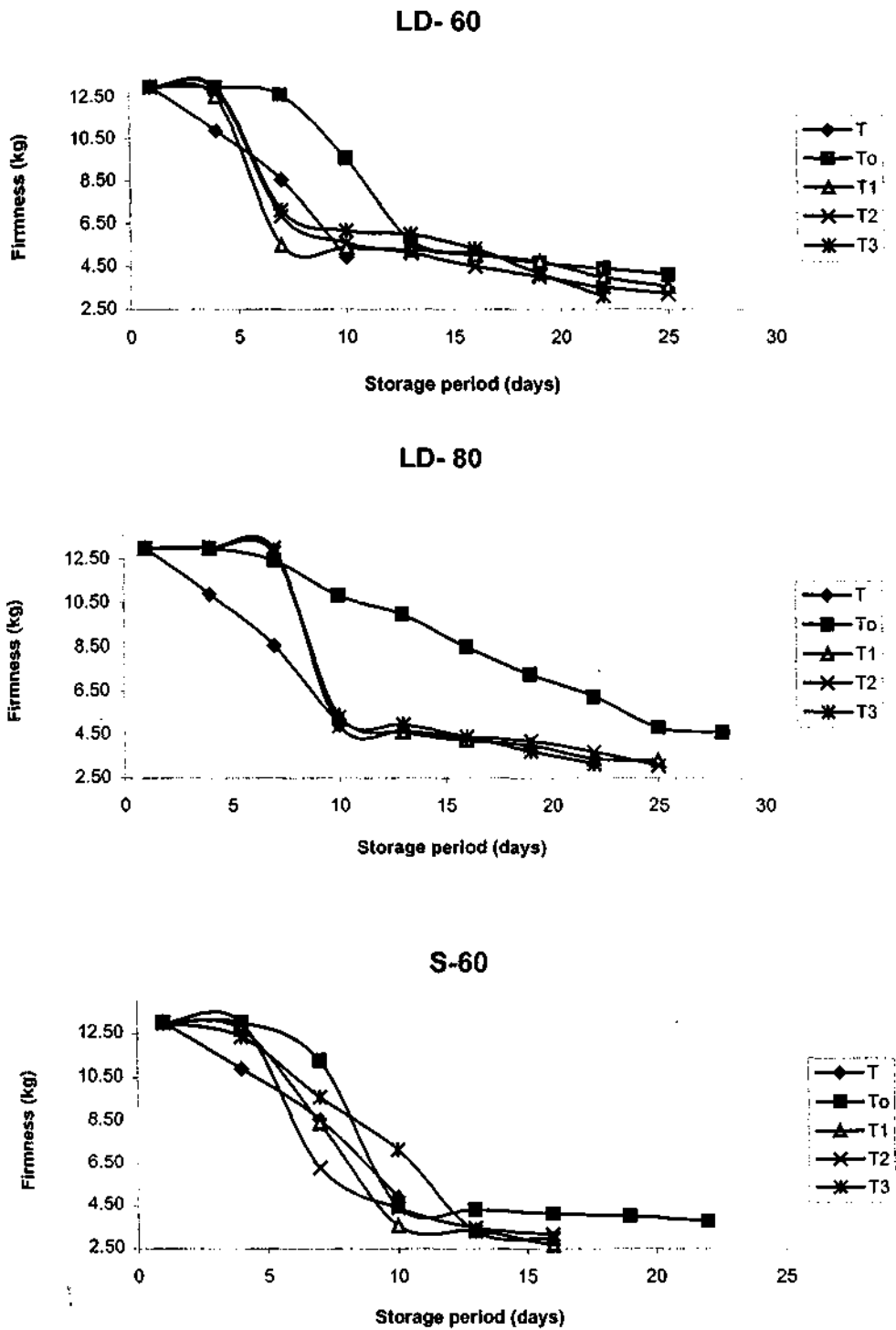


Fig 4.6 Firmness under RT storage conditions

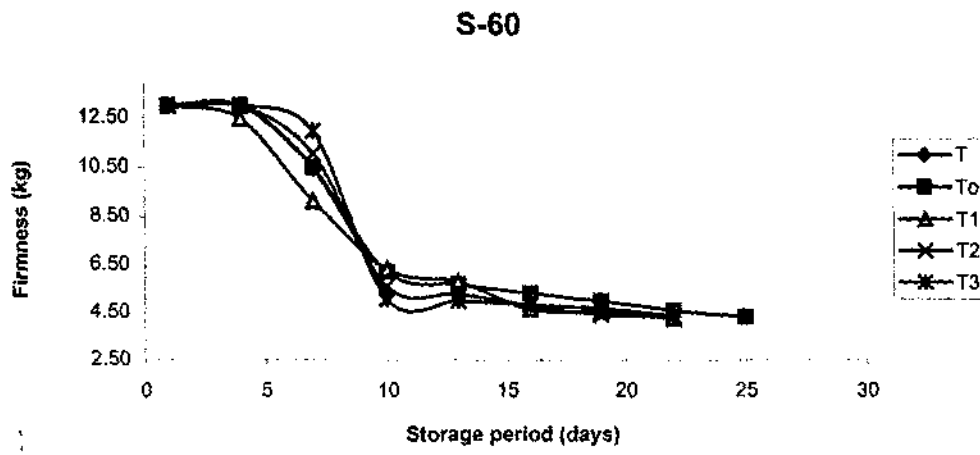
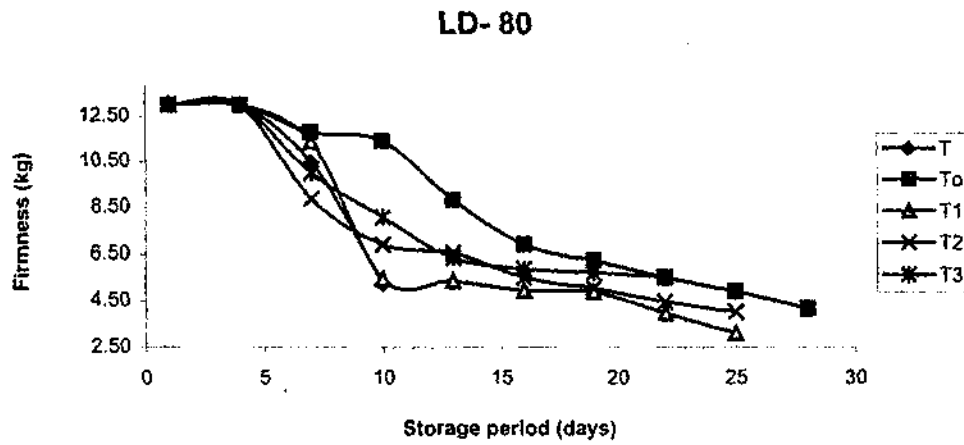
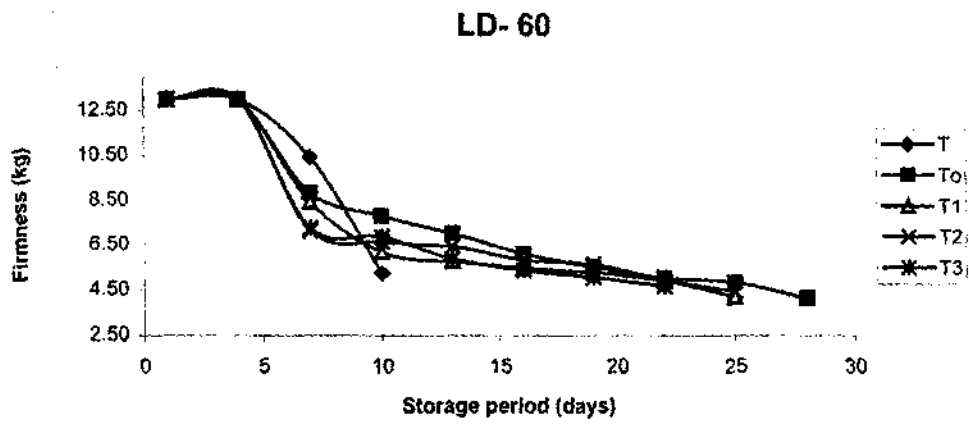


Fig 4.7 Firmness under B&S storage conditions

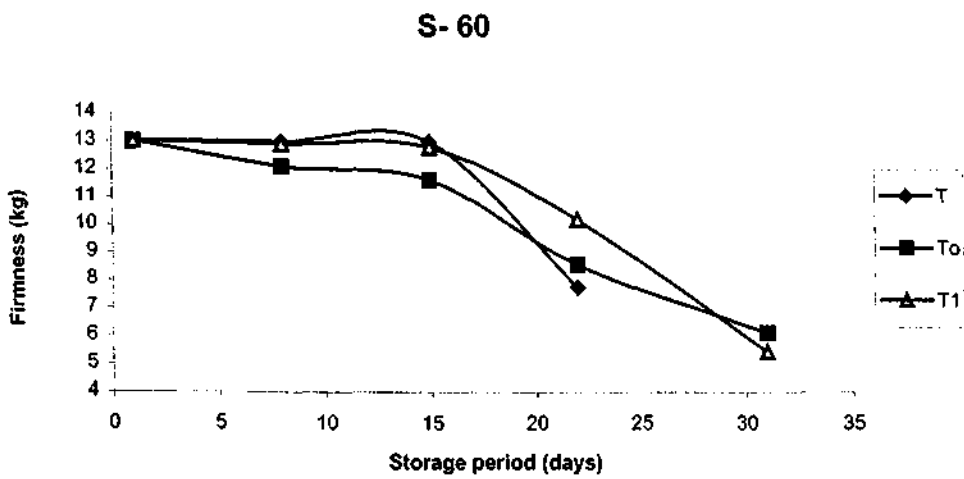
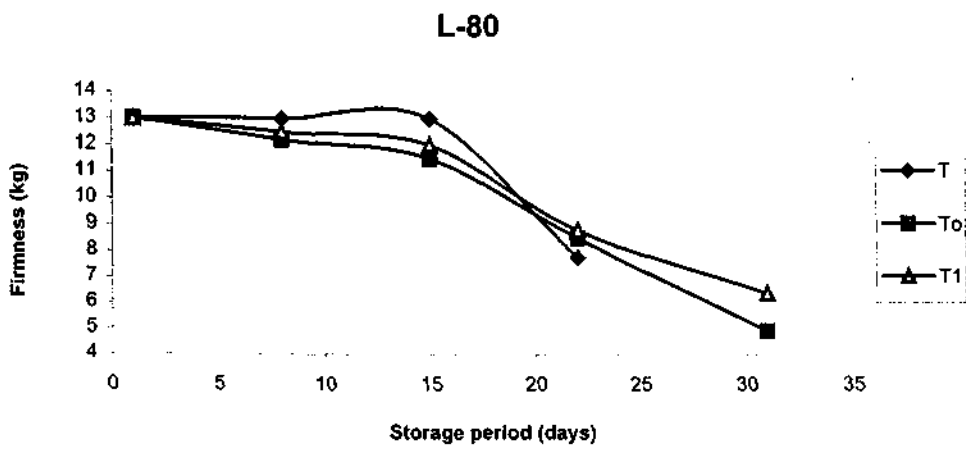
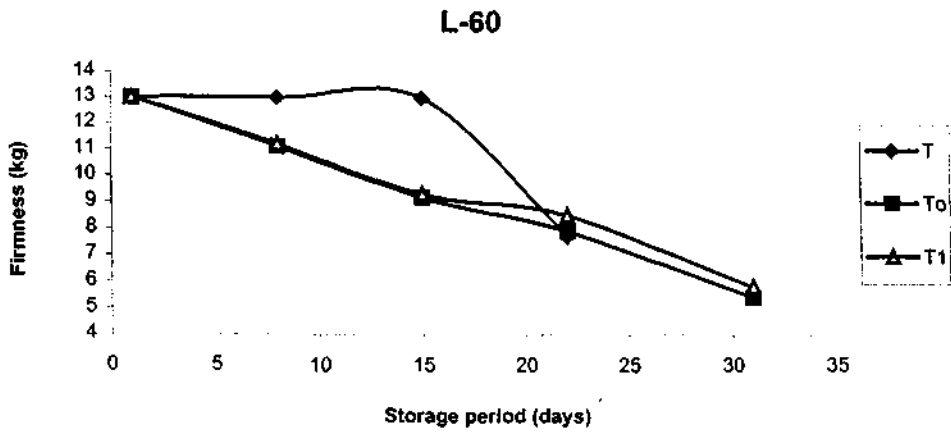


Fig 4.8 Firmness under cold storage conditions

Table 4.9 Average values of firmness(kg) in different films under room temperature storage conditions

| Duration (days) | Control | Different treatments in films | | | | | | | | | | | |
|--------------------|---------|-------------------------------|-------|-------|-------|---------------|-------|-------|-------|-------------|-------|-------|-------|
| | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 10.90 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13 | 12.70 | 13.00 | 12.37 |
| 7 | 8.57 | 13.00 | 11.33 | 12.67 | 9.90 | 12.93 | 13.00 | 8.27 | 6.23 | 11.27 | 8.40 | 6.30 | 9.60 |
| 10 | 4.93 | 7.72 | 5.57 | 5.00 | 6.83 | 5.97 | 5.57 | 5.10 | 4.97 | 4.47 | 3.57 | 4.40 | 7.17 |
| 13 | | 5.67 | 5.10 | 4.53 | 4.40 | 5.00 | 4.83 | 4.53 | 4.80 | 4.33 | 3.33 | 3.47 | 3.30 |
| 16 | | 5.13 | 5.07 | 3.90 | 4.33 | 4.63 | 4.17 | 4.30 | 4.53 | 4.13 | 2.67 | 3.17 | 2.97 |
| 19 | | 4.20 | 4.37 | 3.80 | 3.63 | 3.57 | 3.23 | 3.70 | 4.00 | 4.03 | | | |
| 22 | | 4.03 | 3.97 | 3.47 | 3.40 | 3.47 | 3.07 | 3.37 | 2.97 | 3.80 | | | |
| | | HD--60 | | | | LD--60 | | | | | | | |
| 1 | 13.00 | 13 | 13 | 13 | 13 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 10.90 | 13 | 13 | 13 | 13 | 13 | 12.53 | 12.90 | 13.00 | | | | |
| 7 | 8.57 | 12.82 | 11.75 | 13.00 | 13.00 | 12.63 | 5.50 | 6.87 | 7.13 | | | | |
| 10 | 4.93 | 10.45 | 4.53 | 5.53 | 4.63 | 9.57 | 5.37 | 5.60 | 6.17 | | | | |
| 13 | | 4.80 | 4.27 | 4.85 | 3.80 | 5.70 | 5.27 | 5.13 | 6.00 | | | | |
| 16 | | 4.20 | 4.10 | 4.55 | 3.67 | 5.10 | 5.03 | 4.50 | 5.33 | | | | |
| 19 | | 3.70 | 3.40 | 4.13 | 3.57 | 4.67 | 4.73 | 4.03 | 4.17 | | | | |
| 22 | | 3.60 | 3.27 | 3.50 | 3.50 | 4.40 | 4.00 | 3.53 | 3.13 | | | | |
| 25 | | | | | | 4.12 | 3.57 | 3.23 | | | | | |
| | | HD--80 | | | | LD--80 | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 10.90 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 8.57 | 11.07 | 10.30 | 9.98 | 9.77 | 12.43 | 12.88 | 13.00 | 12.78 | | | | |
| 10 | 4.93 | 6.07 | 5.37 | 6.23 | 5.97 | 10.83 | 5.37 | 4.90 | 5.30 | | | | |
| 13 | | 5.60 | 4.93 | 5.57 | 4.47 | 9.97 | 4.60 | 4.67 | 4.97 | | | | |
| 16 | | 5.23 | 4.40 | 4.90 | 3.93 | 8.50 | 4.23 | 4.40 | 4.40 | | | | |
| 19 | | 4.97 | 4.10 | 4.30 | 3.77 | 7.27 | 4.00 | 4.20 | 3.73 | | | | |
| 22 | | 4.60 | 3.90 | 4.13 | 3.67 | 6.27 | 3.40 | 3.70 | 3.17 | | | | |
| 25 | | 4.23 | | | | 4.83 | 3.30 | 3.07 | | | | | |
| 28 | | | | | | 4.60 | | | | | | | |

Table 4.10 Average values of firmness (kg) in different films under brick & sand storage conditions

| Duration (days) | Control | Different treatments in films | | | | | | | | | | | |
|--------------------|---------|-------------------------------|-------|-------|-------|---------------|-------|-------|-------|-------------|-------|-------|-------|
| | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 12.47 | 13.00 | 13.00 |
| 7 | 10.43 | 12.60 | 10.85 | 8.23 | 13.00 | 7.73 | 10.10 | 10.98 | 7.23 | 10.47 | 9.10 | 11.03 | 11.95 |
| 10 | 5.23 | 6.10 | 6.50 | 5.90 | 6.10 | 5.97 | 5.73 | 6.73 | 5.23 | 6.20 | 6.30 | 5.60 | 5.07 |
| 13 | | 5.33 | 5.77 | 5.23 | 5.03 | 5.40 | 5.03 | 5.20 | 4.80 | 5.67 | 5.77 | 5.27 | 4.97 |
| 16 | | 5.13 | 5.07 | 4.43 | 4.67 | 5.03 | 4.33 | 4.83 | 4.63 | 5.30 | 4.63 | 4.80 | 4.83 |
| 19 | | 4.80 | 4.70 | 4.17 | 3.63 | 4.93 | 4.20 | 4.30 | 4.20 | 4.97 | 4.53 | 4.40 | 4.67 |
| 22 | | 4.50 | 4.33 | 3.97 | 3.53 | 4.47 | 4.03 | 3.93 | 4.00 | 4.60 | 4.23 | 4.33 | 4.37 |
| 25 | | | | | | 4.10 | | | | 4.31 | | | |
| | | HD--60 | | | | LD--60 | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 11.93 | 12.40 | 12.73 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 10.43 | 8.07 | 8.33 | 8.20 | 7.53 | 8.83 | 8.43 | 7.13 | 7.27 | | | | |
| 10 | 5.23 | 6.53 | 5.37 | 6.87 | 5.17 | 7.80 | 6.17 | 6.63 | 6.87 | | | | |
| 13 | | 5.67 | 5.13 | 5.53 | 4.83 | 7.03 | 5.77 | 6.43 | 5.90 | | | | |
| 16 | | 5.20 | 4.57 | 4.70 | 4.60 | 6.10 | 5.47 | 5.83 | 5.37 | | | | |
| 19 | | 4.30 | 4.00 | 4.20 | 4.37 | 5.53 | 5.27 | 5.63 | 5.07 | | | | |
| 22 | | 3.73 | 3.97 | 3.80 | 3.40 | 5.03 | 4.90 | 4.93 | 4.67 | | | | |
| 25 | | | | | | 4.83 | 4.20 | 4.43 | | | | | |
| 28 | | | | | | 4.13 | | | | | | | |
| | | HD--80 | | | | LD--80 | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 11.40 | 12.73 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 10.43 | 11.12 | 9.60 | 10.83 | 11.70 | 11.77 | 11.33 | 8.83 | 9.97 | | | | |
| 10 | 5.23 | 7.10 | 6.87 | 6.70 | 7.93 | 11.40 | 5.43 | 6.90 | 8.07 | | | | |
| 13 | | 6.00 | 5.00 | 4.63 | 5.57 | 8.80 | 5.33 | 6.53 | 6.33 | | | | |
| 16 | | 5.47 | 4.83 | 4.43 | 5.00 | 6.90 | 4.93 | 5.50 | 5.87 | | | | |
| 19 | | 4.97 | 3.97 | 4.30 | 4.60 | 6.20 | 4.87 | 5.03 | 5.70 | | | | |
| 22 | | 4.23 | 3.80 | 3.83 | 3.57 | 5.50 | 3.97 | 4.47 | 5.53 | | | | |
| 25 | | 3.77 | | | | 4.90 | 3.10 | 4.03 | | | | | |
| 28 | | | | | | 4.17 | | | | | | | |

Table 4.11 Average values of firmness (kg) in different films under cold storage conditions

| Duration (days) | Control T | Different treatments in films | | | | | |
|--------------------|--------------|-------------------------------|-------|-------|-------|-------|-------|
| | | HD-40 | | LD-40 | | S-60 | |
| | | T0 | T1 | T0 | T1 | T0 | T1 |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 8 | 13.00 | 10.97 | 11.57 | 11.17 | 12.60 | 12.10 | 12.90 |
| 15 | 13.00 | 9.07 | 10.40 | 9.43 | 12.30 | 11.63 | 12.80 |
| 22 | 7.75 | 8.27 | 7.13 | 8.60 | 9.30 | 8.57 | 10.20 |
| 31 | | 5.17 | 5.83 | 5.90 | 6.07 | 6.10 | 5.43 |
| | | HD-60 | | LD-60 | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | |
| 8 | 13.00 | 9.77 | 11.10 | 11.10 | 11.20 | | |
| 15 | 13.00 | 7.57 | 9.30 | 9.17 | 9.30 | | |
| 22 | 7.75 | 6.50 | 8.43 | 7.90 | 8.50 | | |
| 31 | | 6.43 | 6.33 | 5.40 | 5.80 | | |
| | | HD-80 | | LD-80 | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | |
| 8 | 13.00 | 11.97 | 12.07 | 12.20 | 12.50 | | |
| 15 | 13.00 | 10.90 | 11.23 | 11.50 | 12.00 | | |
| 22 | 7.75 | 8.77 | 10.07 | 8.50 | 8.80 | | |
| 31 | | 5.87 | 7.60 | 4.90 | 6.37 | | |

In cold store, on the contrary, non-perforated films had less firmness (Fig.4.8) than perforated in all films, thicknesses and duration of storage. This was surprising as control fruits had more loss in weight. Here softening in mangoes might be more related to degradation of cell wall polymers than to water loss (McCollum *et al.* 1992). Furthermore, although perforated treatments had high rate of ripening than non-perforated, but mangoes on the other hand were more exposed to cold environment which provided strength to the skin. The thicknesses and type of films had not much effect on firmness during entire period of storage. Similar observations were also reported by McCollum *et al.* (1992), Huddar *et al.* (1995), Sahni and

Khurdiya (1989), Sagar and Khurdiya (1996), Singh and Narayan (1995), Gonzaliz *et al.* (1997) and Chaplin *et al.* (1982).

4.2.3.1 Statistical Analysis: The statistical analysis was applied to only RT & B&S store and top three films LD-60, LD-80 and S-60 were considered. The cold store was not considered as the number of treatments (owing to scarcity of space) and

Table 4.12 Statistical analysis of firmness of mangoes

| Duration (days) | Treat. combination means | | | Factor means | | | CD (5%) | | | |
|--------------------|--------------------------|--------------------------------|------|--------------|------|---------------------|-----------------|-------|-------|----|
| | T | To | T1-3 | Fl | Tt | St | Tt | Fl | TtXFl | St |
| 10 | 5.08 | 8.69 | 6.06 | 6.77 | 8.38 | 5.95 | 1.39 (2.31). | 1.21 | - | - |
| | | 11.12 | 6.00 | 7.28 | 5.33 | 6.71 | | | | |
| | | 5.34 | 5.31 | 5.32 | 5.67 | 6.44 | | | | |
| 16 | | 5.60 | 5.26 | 5.34 | 6.01 | | 0.875 | 0.758 | - | - |
| | | 7.70 | 4.89 | 5.59 | 4.49 | | | | | |
| | | 4.72 | 3.85 | 4.06 | 4.70 | 4.80 | | | | |
| 19 | | 5.10 | 4.82 | 4.89 | 5.92 | | - | - | - | - |
| | | 6.74 | 4.59 | 5.13 | 4.72 | | | | | |
| | | | | | 4.73 | 4.68 | | | | |
| 22 | | 4.72 | 4.19 | 4.32 | 5.30 | | - | - | - | - |
| | | 5.89 | 4.04 | 4.50 | 4.07 | | | | | |
| | | | | | 4.16 | 4.13 | | | | |
| NOTE: | | Tt: Treatment (To, T1, T2, T3) | | | | St: Store (RT, B&S) | | | | |
| | | Fl: Film (LD-60, LD-80, S-60) | | | | TtXFl: Interaction | | | | |

time of recording were not same. The statistical results are shown in Table 4.12. The store means were 5.95 and 6.71 respectively indicating that treatments in B&S store has higher firmness than RT store. The film means for best film (LD-80) were 7.28, 5.59, 5.13 and 4.50 after 10, 16, 19 & 22nd days of storage and these values were higher than other two films. The treatment means for best treatment (T₀) were

8.38, 6.01, 5.92 and 5.30 after respective period of storage. Thus, treatment T₀ had an appreciable edge in firmness over others. The film and treatment had only significant effect upto 16th day of storage as indicated by CD (5 percent) values thereafter either their individual or interaction between them has no significant effect. All these findings verified our experimental results.

4.2.4 Total Soluble Solids (TSS):

The average values of TSS variations in different treatments of all films and storage environments are given in Table 4.13-4.15 and trends of change in TSS in top three films have been shown in Fig.4.9-4.11.

It is evident that TSS increased with the duration of storage irrespective of treatment; reached its peak value Fig.4.9 and then started declining. The increase in TSS might be associated with loss of moisture and transformation (hydrolysis) of pectic substances, starch or other polysaccharides into soluble sugars. The decline in some treatments after attaining peak might be due to degradation of total soluble substances due to prolonged period of storage (Singh and Singh, 1992; Sagar and Khurdiya, 1996). Mahajan and Sharma (1996) attributed the increase in TSS to increase in concentration of organic solutes as a consequence of water loss. Sahni and Khurdiya (1989) stated that during decline of TSS, moisture was transferred from peel to pulp as theorized by Leley *et al.* (1943). The rate of change in TSS was found to be higher in perforated treatments than non-perforated treatments during initial period of 10-16 days. So higher is the rate; the earlier it reaches peak and started declining. Singh and Singh (1992) reported that the slow but gradual rise in TSS of fruits wrapped in films might be due to delay in ripening and senescence and

wrapped perforated treatments were found to be best in retaining TSS and showed marked superiority over other treatments. Rameshwar *et al.* (1979b) reported that wrapping decreases the TSS slightly and tended to lower acid loss during ripening. Again no significant difference in TSS values was found between three types of films (LD, HD, S-60). But thicknesses of the films has some effect on TSS especially during the middle period (16-19th day) where 40 gauge film resulted in lower TSS than higher gauge films as it has reached its peak value earlier than others which had a slower rate.

Similar trends were found in B&S store (Fig.4.10) but TSS values were slightly lower than RT store in respective treatments. This was attributed to lower rate of moisture loss in B&S store. The average peak values (Table 4.16) for non-perforated films were 17.63, 17.73 and 18 °Brix in HDPE, LDPE and S-60 films respectively while the corresponding values in perforated films were 17.58, 18.38 and 19.13 °Brix which implied that perforated treatments had slightly higher peak values of TSS than non-perforated ones. However, in B&S store, the trend was otherwise as is indicated by average peak TSS values of 17.47, 18.53 & 19.0 and 17.23, 17.66 & 16.87 °Brix in non-perforated and perforated treatments of LDPE, HDPE and S-60 films, respectively. Another conclusion that we can make is that irrespective of the type of store, the average peak values of TSS was slightly higher in LDPE than HDPE films owing to higher loss of moisture. Now comparing corresponding treatments in each store and type of film, it was observed that while non-perforated HDPE film treatments in RT store had slightly higher TSS than its counterpart in B&S store. But trend was in reverse direction in LDPE film treatments

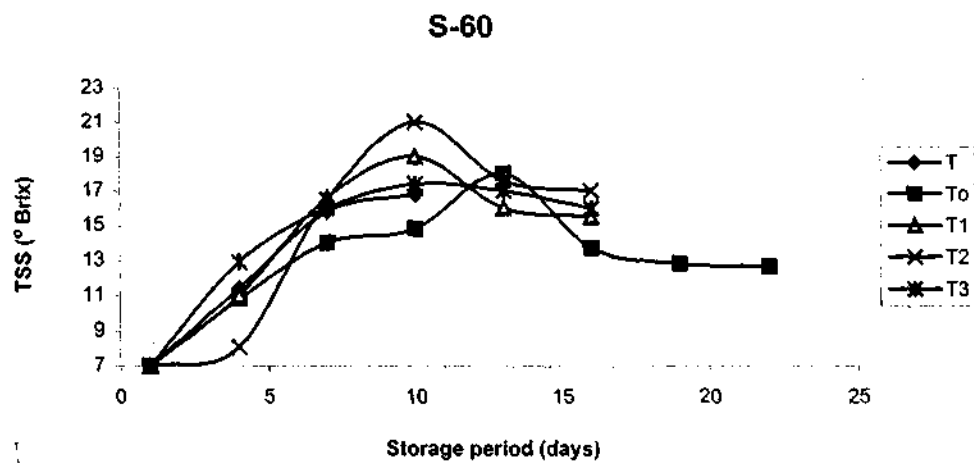
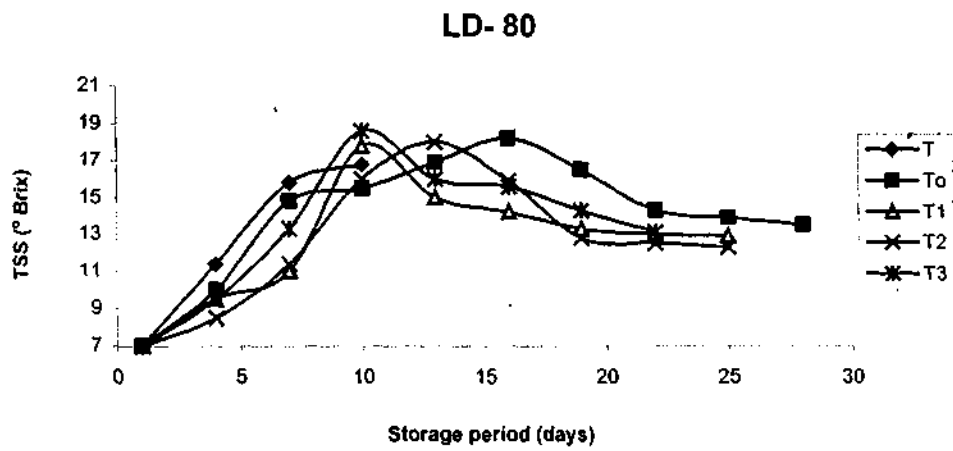
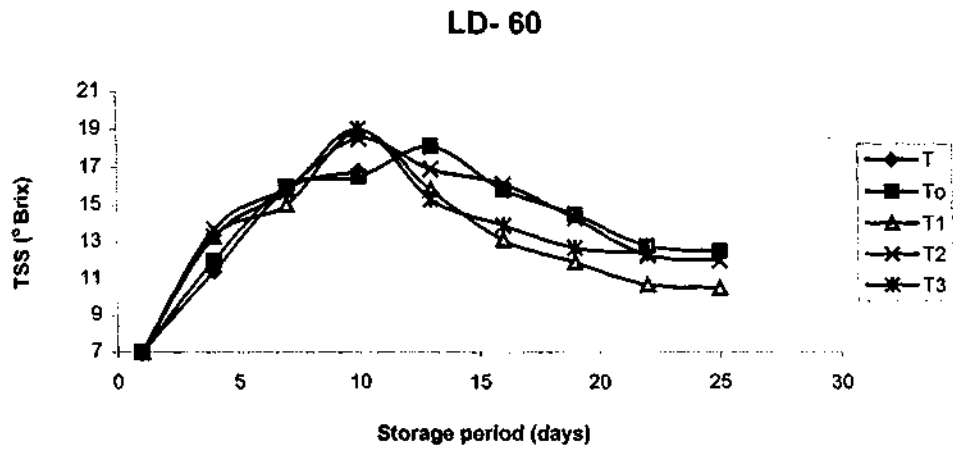


Fig 4.9 TSS under RT storage conditions

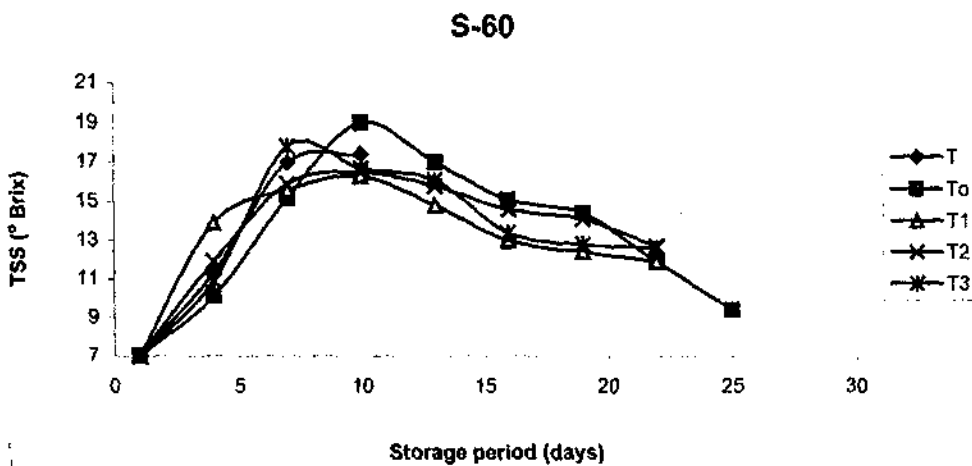
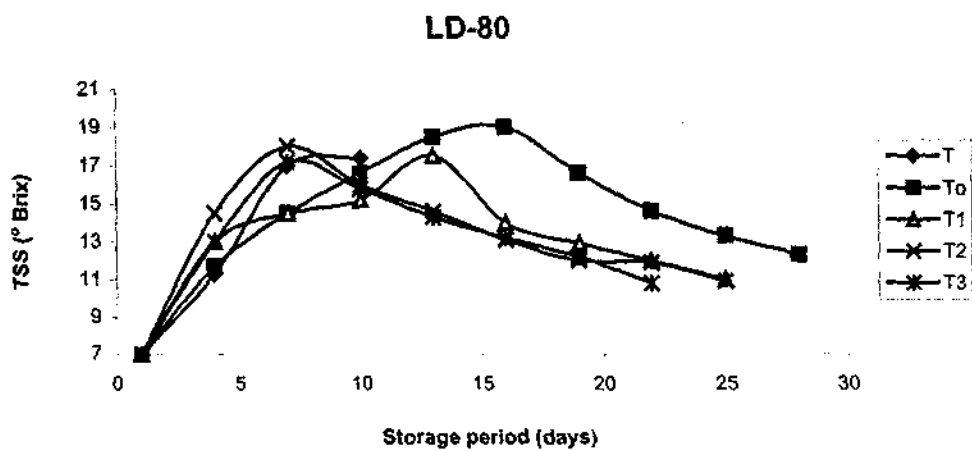
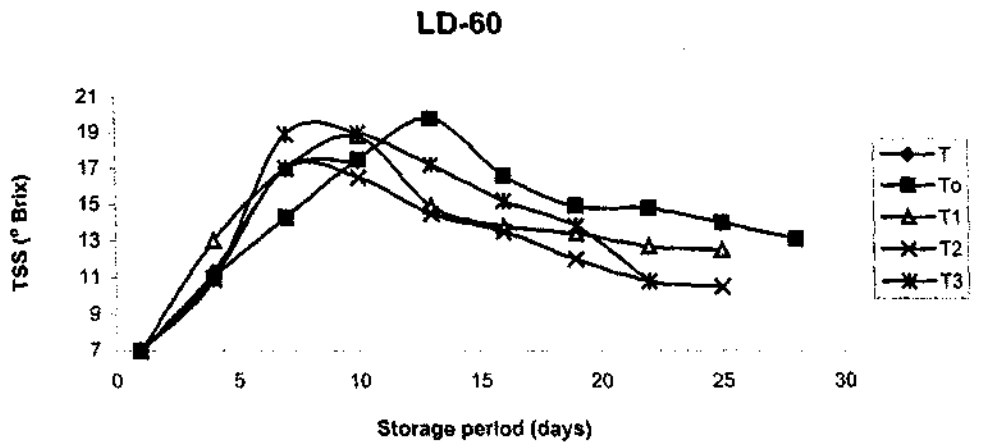


Fig 4.10 TSS under B&S storage conditions

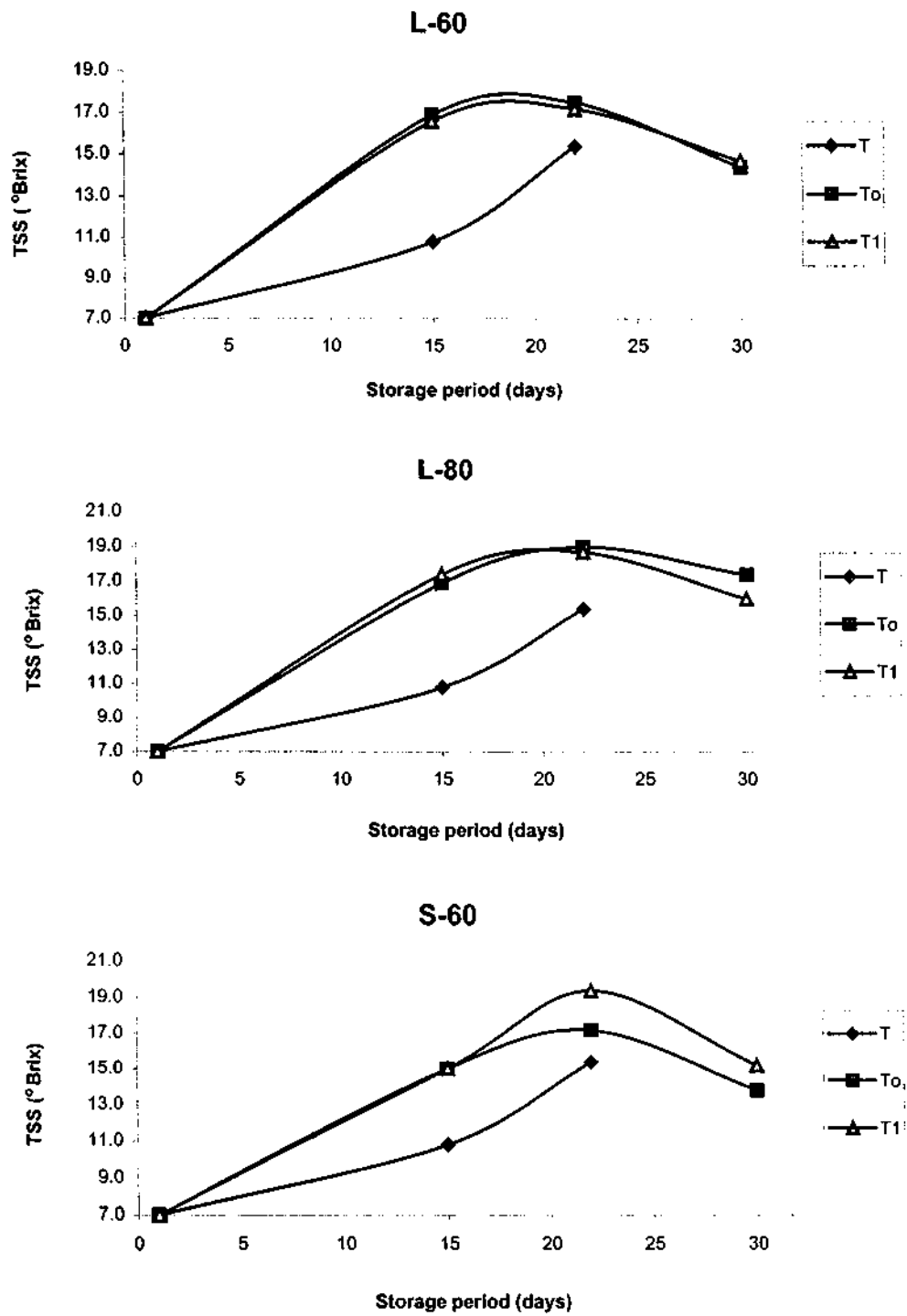


Fig 4.11 TSS under cold storage conditions

Table 4.13 Average values of TSS (°brix) in different films under room temperature storage conditions

| (days) | Control | Different treatments in films | | | | | | | | | | | |
|--------|---------|-------------------------------|------|------|------|--------------|------|------|------|-------------|------|------|------|
| | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 |
| 4 | 11.4 | 9.5 | 9.5 | 9.4 | 9.0 | 10.9 | 11.5 | 11.7 | 8.9 | 10.8 | 11.0 | 8.1 | 12.9 |
| 7 | 15.8 | 12.2 | 13.0 | 11.0 | 9.4 | 14.8 | 19.4 | 12.7 | 11.5 | 14.0 | 16.6 | 16.5 | 16.0 |
| 10 | 16.8 | 16.5 | 16.3 | 17.0 | 19.0 | 15.6 | 17.5 | 17.5 | 15.0 | 14.8 | 19.0 | 21.0 | 17.4 |
| 13 | | 16.8 | 17.5 | 15.6 | 14.8 | 16.9 | 15.8 | 16.8 | 17.7 | 18.0 | 16.0 | 17.6 | 17.0 |
| 16 | | 16.5 | 12.8 | 15.0 | 14.3 | 14.0 | 14.3 | 16.0 | 15.8 | 13.7 | 15.5 | 17.0 | 16.0 |
| 19 | | 12.2 | 11.8 | 14.0 | 13.8 | 13.2 | 10.8 | 14.9 | 12.8 | 12.8 | | | |
| 22 | | 11.8 | 11.5 | 13.5 | 13.6 | 12.5 | 10.4 | 14.4 | 12.4 | 12.6 | | | |
| | | HD-60 | | | | LD-60 | | | | | | | |
| 1 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | | | | |
| 4 | 11.4 | 9.6 | 9.9 | 8.9 | 9.5 | 12.0 | 13.3 | 13.7 | 13.3 | | | | |
| 7 | 15.8 | 12.0 | 12.3 | 11.8 | 13.5 | 16.0 | 15.0 | 15.9 | 15.7 | | | | |
| 10 | 16.8 | 18.5 | 16.5 | 18.3 | 19.3 | 16.5 | 18.9 | 18.5 | 19.0 | | | | |
| 13 | | 17.7 | 15.6 | 17.5 | 17.5 | 18.1 | 15.8 | 16.9 | 15.3 | | | | |
| 16 | | 17.2 | 14.0 | 16.0 | 16.2 | 15.8 | 13.1 | 16.1 | 13.9 | | | | |
| 19 | | 16.6 | 12.5 | 14.3 | 15.1 | 14.5 | 11.9 | 14.3 | 12.7 | | | | |
| 22 | | 15.2 | 12.1 | 13.2 | 14.2 | 12.8 | 10.7 | 12.3 | 12.4 | | | | |
| 25 | | | | | | 12.5 | 10.5 | 12.0 | | | | | |
| | | HD-80 | | | | LD-80 | | | | | | | |
| 1 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | | | | |
| 4 | 11.4 | 9.5 | 9.5 | 9.5 | 9.5 | 10.0 | 9.5 | 8.5 | 9.5 | | | | |
| 7 | 15.8 | 14.5 | 11.8 | 11.1 | 11.5 | 14.8 | 11.0 | 11.4 | 13.3 | | | | |
| 10 | 16.8 | 15.3 | 17.0 | 17.0 | 16.0 | 15.5 | 17.8 | 16.0 | 18.6 | | | | |
| 13 | | 17.6 | 16.2 | 16.0 | 16.6 | 16.9 | 15.0 | 18.0 | 16.0 | | | | |
| 16 | | 17.0 | 14.0 | 14.3 | 13.3 | 18.2 | 14.2 | 15.9 | 15.6 | | | | |
| 19 | | 13.7 | 12.8 | 14.0 | 12.6 | 16.5 | 13.3 | 12.8 | 14.3 | | | | |
| 22 | | 12.8 | 12.2 | 13.3 | 11.9 | 14.3 | 13.0 | 12.5 | 13.1 | | | | |
| 25 | | 12.0 | | | | 13.9 | 12.9 | 12.3 | | | | | |
| 28 | | | | | | 13.5 | | | | | | | |

Table 4.14 Average values of TSS (°brix) in different films under brick & sand storage conditions

| Duration (days) | Control | Different treatments in films | | | | | | | | | | | |
|--------------------|---------|-------------------------------|------|------|------|--------------|------|------|------|-------------|------|------|------|
| | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 |
| 4 | 11.3 | 12.8 | 13.9 | 15.0 | 14.0 | 12.9 | 13.9 | 12.0 | 11.2 | 10.1 | 13.9 | 11.9 | 10.9 |
| 7 | 17.0 | 16.2 | 17.5 | 17.7 | 15.0 | 15.9 | 17.0 | 17.5 | 15.9 | 15.2 | 15.6 | 15.9 | 17.8 |
| 10 | 17.4 | 16.6 | 18.6 | 16.3 | 16.5 | 16.5 | 17.2 | 15.2 | 15.0 | 19.0 | 16.3 | 16.5 | 16.7 |
| 13 | | 17.0 | 15.0 | 15.0 | 15.0 | 16.8 | 18.2 | 14.7 | 14.5 | 17.0 | 14.8 | 15.8 | 16.1 |
| 16 | | 13.3 | 13.0 | 14.0 | 13.8 | 14.3 | 15.5 | 12.6 | 13.5 | 15.1 | 13.0 | 14.6 | 13.4 |
| 19 | | 12.8 | 12.6 | 10.7 | 12.9 | 13.1 | 13.4 | 10.4 | 12.8 | 14.4 | 12.4 | 14.1 | 12.8 |
| 22 | | 10.0 | 10.8 | 10.5 | 12.4 | 12.0 | 10.6 | 10.0 | 11.0 | 11.9 | 11.9 | 12.7 | 12.6 |
| 25 | | | | | | 11.7 | | | | 9.4 | | | |
| | | HD-60 | | | | LD-60 | | | | | | | |
| 1 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | | | | |
| 4 | 11.3 | 10.5 | 11.9 | 12.0 | 12.9 | 11.0 | 13.0 | 11.0 | 10.9 | | | | |
| 7 | 17.0 | 15.1 | 14.0 | 14.6 | 14.2 | 14.3 | 17.0 | 17.0 | 18.9 | | | | |
| 10 | 17.4 | 16.0 | 17.6 | 15.2 | 16.7 | 17.5 | 18.8 | 16.5 | 19.0 | | | | |
| 13 | | 17.4 | 15.8 | 14.9 | 13.0 | 19.8 | 14.9 | 14.5 | 17.2 | | | | |
| 16 | | 15.0 | 14.0 | 14.0 | 12.5 | 16.6 | 13.8 | 13.5 | 15.2 | | | | |
| 19 | | 14.3 | 13.3 | 13.2 | 12.3 | 14.9 | 13.4 | 12.0 | 13.8 | | | | |
| 22 | | 13.2 | 13.0 | 12.8 | 12.0 | 14.8 | 12.7 | 10.8 | 10.8 | | | | |
| 25 | | 12.1 | | | | 14.0 | 12.5 | 10.5 | | | | | |
| 28 | | | | | | 13.1 | | | | | | | |
| | | HD-80 | | | | LD-80 | | | | | | | |
| 1 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | | | | |
| 4 | 11.3 | 15.0 | 15.1 | 14.8 | 12.1 | 11.7 | 13.0 | 14.5 | 13.0 | | | | |
| 7 | 17.0 | 16.7 | 16.6 | 17.6 | 17.8 | 14.5 | 14.5 | 18.0 | 17.2 | | | | |
| 10 | 17.4 | 17.0 | 17.6 | 17.5 | 15.7 | 16.6 | 15.2 | 16.0 | 15.8 | | | | |
| 13 | | 18.0 | 17.1 | 16.5 | 14.9 | 18.5 | 17.5 | 14.6 | 14.3 | | | | |
| 16 | | 14.0 | 14.2 | 13.8 | 14.4 | 19.0 | 14.0 | 13.1 | 13.2 | | | | |
| 19 | | 13.0 | 12.1 | 13.0 | 14.0 | 16.6 | 12.9 | 12.0 | 12.2 | | | | |
| 22 | | 12.2 | 11.8 | 11.2 | 11.0 | 14.6 | 12.0 | 11.9 | 10.8 | | | | |
| 25 | | 11.7 | | | | 13.3 | 11.0 | 10.9 | | | | | |
| 28 | | | | | | 12.3 | | | | | | | |

with a difference of about 1°brix. Perforated treatments, on the other hand, had no definite trend irrespective of treatment, type of film and store type.

In cold store perforated treatments had (Fig.4.11) higher peak value of TSS than their counterparts in all types of films. The average peak values for HDPE and S-60 were lower than LDPE. The peak values were 17.6, 18.07 & 17.2 in non-perforated and 18.30, 18.53 & 19.4°brix in respective types of films. Again in non-perforated film treatments, the average peak value increased with the thicknesses of

Table 4.15 Average values of TSS (°brix) in different films under cold storage conditions

| Duration (days) | Control T | Different treatments in films | | | | | |
|--------------------|--------------|-------------------------------|------|-------|------|------|------|
| | | HD-40 | | LD-40 | | S-60 | |
| | | T0 | T1 | T0 | T1 | T0 | T1 |
| 1 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 |
| 15 | 10.8 | 15.5 | 14.8 | 16.5 | 19.4 | 15.0 | 15.0 |
| 22 | 15.4 | 17.4 | 22.3 | 17.7 | 19.7 | 17.2 | 19.4 |
| 30 | | 14.7 | 14.9 | 16.5 | 13.8 | 13.8 | 15.2 |
| | | HD-60 | | LD-60 | | | |
| 1 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | | |
| 15 | 10.8 | 17.4 | 14.5 | 16.9 | 16.6 | | |
| 22 | 15.4 | 19.0 | 17.9 | 17.5 | 17.2 | | |
| 30 | | 12.6 | 17.5 | 14.4 | 14.7 | | |
| | | HD-80 | | LD-80 | | | |
| 1 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | | |
| 15 | 10.8 | 13.4 | 12.8 | 16.9 | 17.4 | | |
| 22 | 15.4 | 16.4 | 13.5 | 19.0 | 18.7 | | |
| 30 | | 12.2 | 14.7 | 17.4 | 16.0 | | |

the films in RT and B&S stores irrespective of type of film. There was no definite trend in perforated treatments cold storage has no definite trend in either of treatments. In the end, LDPE film particularly at higher thicknesses irrespective of the store had higher peak values of TSS. Our findings are in conformity with the results reported by McCollum *et al.* (1997); Dhalla and Hanson (1988); Singh and

Table 4.16 Peak values of TSS in different films and storage environments

| Type of store | Type of film | Peak TSS (°brix) | | | | Average peak TSS | | | | |
|---------------|--------------|--|-------|-------|-------|------------------|----------|----------|----------|----------|
| | | To | T1 | T2 | T3 | To | T1-3 | G. Avg. | | |
| RT | HDPE | 16.80 | 17.50 | 17.00 | 19.00 | 17.63 | 17.58 | | | |
| | | 18.50 | 16.50 | 18.30 | 19.30 | | | | | |
| | | 17.60 | 17.00 | 17.00 | 16.60 | | | | | |
| | LDPE | 16.90 | 19.40 | 17.50 | 17.70 | 17.73 | 18.38 | | | |
| | | 18.10 | 18.90 | 18.50 | 19.00 | | | | | |
| | | 18.20 | 17.80 | 18.00 | 18.60 | | | | | |
| | S-60 | 18.00 | 19.00 | 21.00 | 17.40 | 18.0 | 19.1 | | | |
| | | | | | | | (17.79). | | (18.36). | (18.08). |
| | B&S | HDPE | 17.00 | 18.60 | 17.70 | 16.50 | 17.47 | | 17.23 | |
| 17.40 | | | 17.60 | 15.20 | 16.70 | | | | | |
| 18.00 | | | 17.60 | 17.60 | 17.80 | | | | | |
| LDPE | | 16.80 | 18.20 | 17.50 | 15.90 | 18.53 | 17.66 | | | |
| | | 19.80 | 18.80 | 17.00 | 18.90 | | | | | |
| | | 19.00 | 17.50 | 18.00 | 17.20 | | | | | |
| S-60 | | 19.00 | 16.30 | 16.50 | 17.80 | 19.00 | 16.87 | | | |
| | | | | | | (18.33). | (17.25). | (17.79). | | |
| CS | | HDPE | 17.40 | 22.30 | - | - | 17.60 | 18.30 | | |
| | 19.00 | | 17.90 | - | - | | | | | |
| | 16.40 | | 14.70 | - | - | | | | | |
| | LDPE | 17.70 | 19.70 | - | - | 18.07 | 18.53 | | | |
| | | 17.50 | 17.20 | - | - | | | | | |
| | | 19.00 | 18.70 | - | - | | | | | |
| | S-60 | 17.20 | 19.40 | - | - | 17.20 | 19.40 | | | |
| | | | | | | | (17.62). | (18.74). | (18.18). | |
| | NOTE: | To: Wrapped non perforated T1: perforated (0.78%) T2: perforated (0.48%) T3: perforated (0.26%) | | | | | | | | |

Singh (1992); Sagar and Khurdiya (1996); Ryall and Penzer (1982); Mahajan and Sharma (1996); Mukherjee and Srivastava (1979); Rameshwar *et al.* (1979b).

Table 4.17 Statistical analysis of TSS of mangoes

| Duration (days) | Treat. combination means | | | Factor means | | | CD (5%) | | | |
|--------------------|--------------------------|-----------------------------|-------|--------------|-------|--------------------|---------|----|-------|----|
| | T | To | T1-3 | FI | Tt | St | Tt | FI | TtXFI | St |
| 10 | 17.10 | 17.00 | 18.45 | 18.09 | 16.65 | 17.68 | - | - | - | - |
| | | 16.05 | 16.57 | 16.44 | 17.67 | 17.02 | | | | |
| | | 16.90 | 17.82 | 17.59 | 17.42 | | | | | |
| | | | | | 17.75 | | | | | |
| 16 | | 16.20 | 14.27 | 14.75 | 16.40 | | 1.611 | - | - | - |
| | | 18.60 | 14.33 | 15.40 | 13.93 | | | | | |
| | | 14.40 | 14.92 | 14.79 | 15.03 | | | | | |
| | | | | | 14.55 | | | | | |
| 19 | | 14.70 | 13.02 | 13.44 | 15.63 | | 1.630 | - | - | - |
| | | 16.55 | 12.92 | 13.83 | 12.88 | | | | | |
| | | | | | 12.78 | | | | | |
| | | | | | 13.25 | | | | | |
| 22 | | 13.80 | 11.62 | 12.16 | 14.13 | | - | - | - | - |
| | | 14.45 | 12.22 | 12.78 | 12.10 | | | | | |
| | | | | | 11.88 | | | | | |
| | | | | | | | | | | |
| NOTE: | | Tt: Treatment(To,T1,T2,T3) | | | | St: Store (RT,B&S) | | | | |
| | | FI: Film (LD-60,LD-80,S-60) | | | | TtxFI: Interaction | | | | |

4.2.4.1 Statistical Analysis: The results of statistical analysis after 10, 16, 19 and 22 days of storage are presented in Table 4.17. It is evident that the store means for RT store (17.68) was higher than B&S store (17.02) which indicated that RT gave higher TSS than B&S owing to more PLW. A perusal of the table 4.17 showed that initially treatment means for perforated films was higher than its counter part upto 10-13 days but afterwards the trend was reversed which is due to the fact that treatments with perforations reached their peak values earlier than non-perforated ones. Again film means was lower in LD-80 than other two films during initial period. But trend was reversed after 16th day which might be due to the fact that higher the

thickness of the film, the slower it reaches its peak value and hence the results. The comparison of individual film means at all durations showed that film had insignificant effect on TSS while treatment had during middle period but no effect during initial and final period of storage because it was the middle period during which peak values were achieved. The CD (5 percent) values for treatments were 1.611 & 1.63 at 16 and 19th day of storage. The interaction between film and treatments generally had no effect.

4.2.5 pH Values:

The pH values in different treatments of all films and in three storage environments are presented in Table 4.18-4.20 and trends of change in pH values in top three films are shown in Fig.4.12-4.14.

It is clear from Fig.4.12 that pH increased with the duration of storage in all the treatments. The increase in pH could be attributed to continuous fall in acidity (Joshi and Roy, 1985; Thomas and Janave, 1975; Roy and Pande, 1983). The sudden rise in pH in control fruits after 4th day indicated that ripening had started which resulted in increase in sugar and fall in acidity. After 4th day which represented onset of ripening in control fruits, the pH values increased at a much higher rate than wrapped one and difference in pH values increased with the duration of storage. The film wrapped treatments having lesser loss of moisture and delayed ripening might be responsible for minimizing changes in acidity and so was the pH (Singh and Singh, 1992). There was no definite trend in perforated as well as non-perforated treatments of HDPE films. In LDPE films, changes in pH were significantly slower than its counterparts in HDPE films. The pH change was slower in non-perforated

treatments compared to perforated and pH values increased with the level of perforations. It seems that availability of O₂ had an effect on the rate of ripening and hence pH. A pH of 5.50 is the threshold limit (Panstastico, 1975) which indicated the onset of over ripening (passing of climacteric peak). The mangoes in non-perforated treatments crossed this limit after 16, 16 & 19 and 16, 22 & 25th day of storage in HDPE and LDPE films and respective thicknesses. The non-perforated treatments in S-60 films had significant edge (19th day) over perforated treatments (13th day) as far as this threshold limit is concerned. This was on account of imperfect shrink wrapping in perforated films and hence more exposure of fruits to atmospheric air.

The change in pH in non-perforated treatments of B&S store (Fig.4.13) was slower than its counterparts in RT store. This might be due to lower temperature (4-6°C less) in B&S store. However, there was no significant difference in pH values of perforated treatments irrespective of type of film, thicknesses and level of perforations. The threshold limit was crossed after 16, 19, 19 and 19, 22, 25th day of storage in respective thicknesses of HDPE and LDPE films. While S-60 film crossed this limit after 19th day.

In cold storage, no significant difference was observed in pH value (Fig.4.14) of both perforated and non-perforated treatments. However, perforated treatments had higher pH values than non-perforated treatments during entire period of storage. Moreover, pH increased with the thicknesses of the film in LDPE and HDPE films. This may be attributed to higher degree of protection provided by higher thicknesses of films from cold. Thus, this trend was opposite to that prevailing in RT and B&S store where higher thickness provided protection from hot conditions. The S-60 film

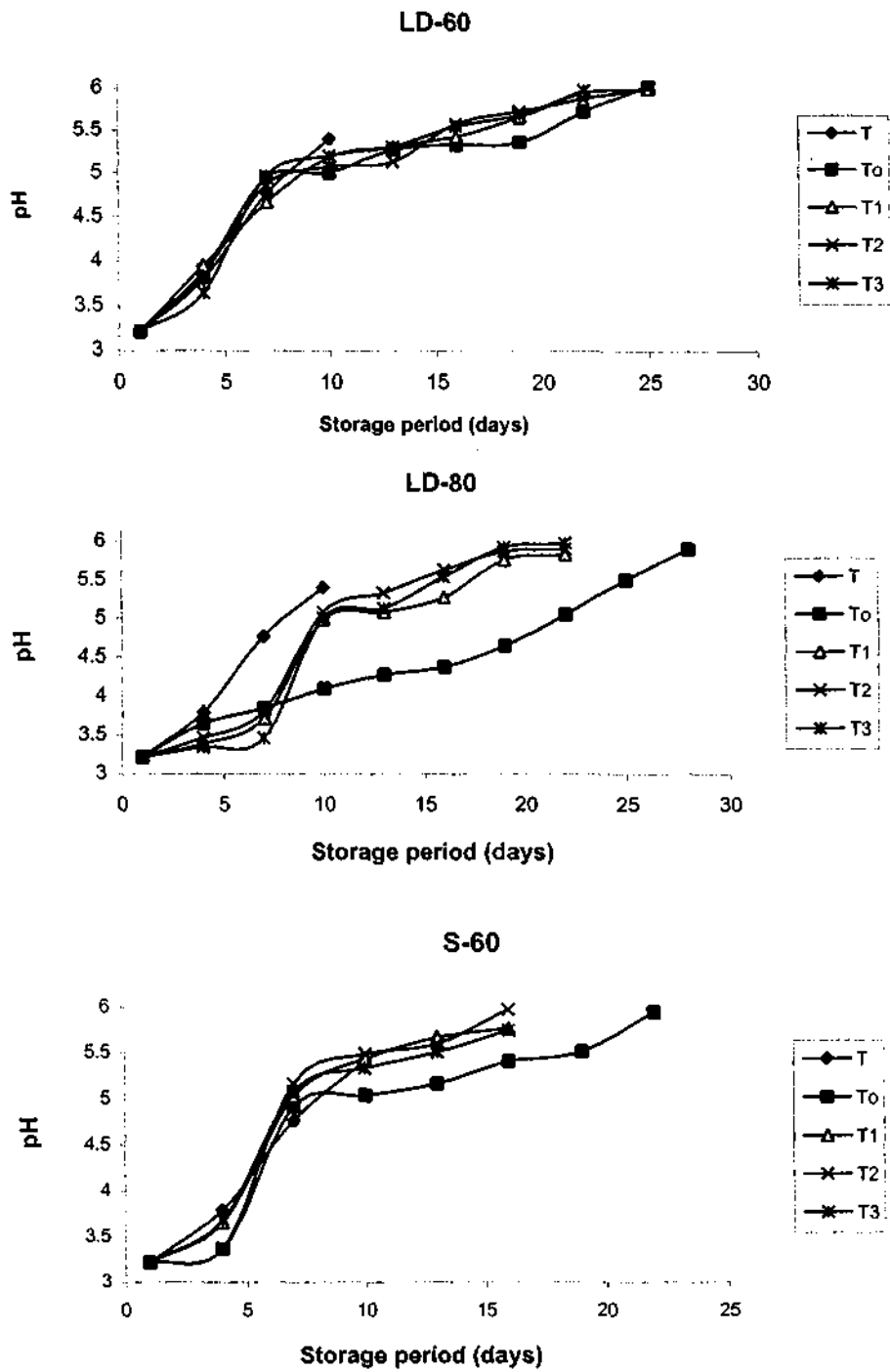


Fig 4.12 pH value under RT storage conditions

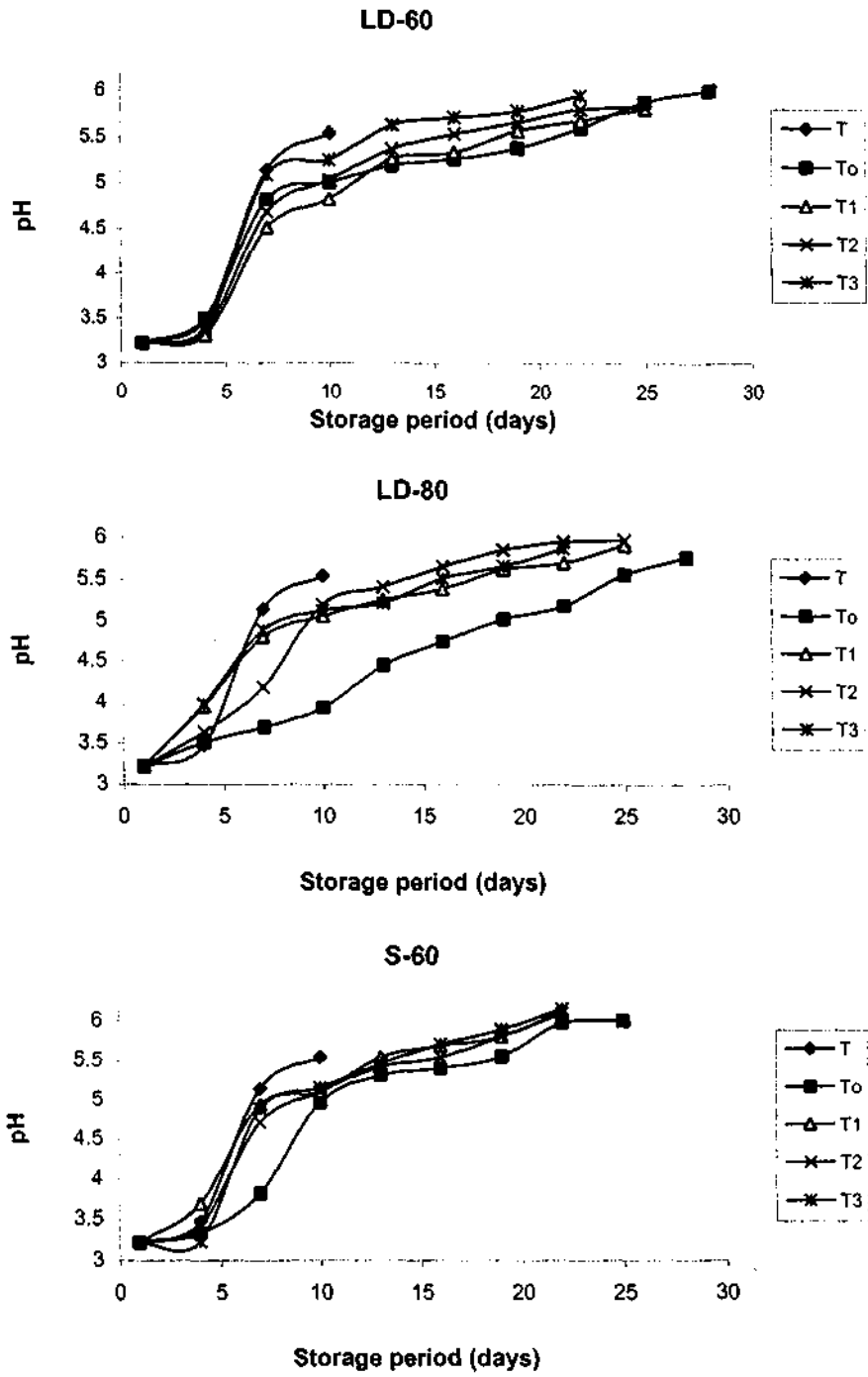


Fig 4.13 pH value under B&S storage conditions

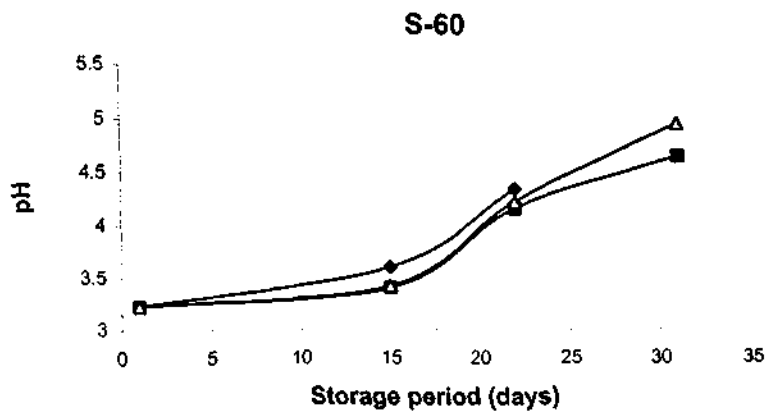
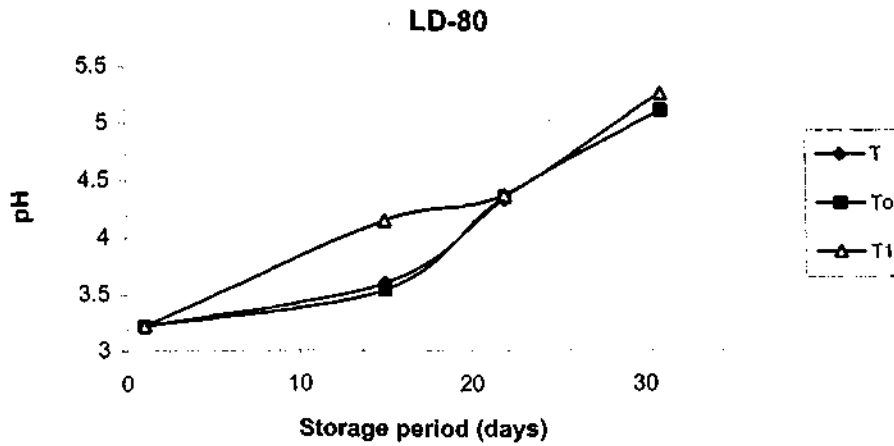
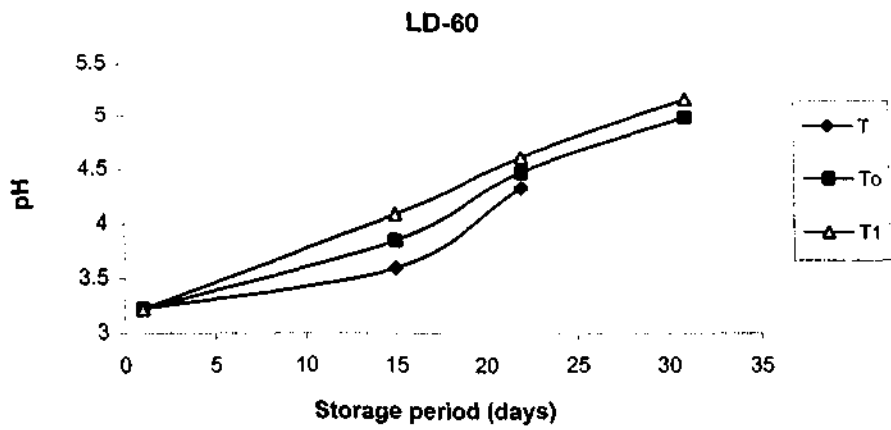


Fig 4.14 pH value under cold storage conditions

Table 4.18 Average values of pH in different films under room temperature storage conditions

| Duration (days) | Control | Different treatments in films | | | | | | | | | | | |
|--------------------|---------|-------------------------------|------|------|------|--------------|------|------|------|-------------|------|------|------|
| | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 |
| 4 | 3.80 | 3.31 | 3.48 | 3.25 | 3.39 | 3.38 | 3.32 | 3.38 | 3.42 | 3.37 | 3.66 | 3.38 | 3.69 |
| 7 | 4.77 | 3.69 | 3.56 | 3.51 | 3.58 | 4.20 | 4.38 | 4.45 | 4.36 | 4.92 | 5.03 | 5.17 | 5.09 |
| 10 | 5.41 | 5.09 | 5.11 | 4.99 | 4.78 | 5.14 | 5.21 | 5.13 | 5.23 | 5.04 | 5.44 | 5.49 | 5.34 |
| 13 | | 5.25 | 5.39 | 5.55 | 5.47 | 5.43 | 5.44 | 5.30 | 5.56 | 5.17 | 5.67 | 5.60 | 5.51 |
| 16 | | 5.69 | 5.64 | 5.68 | 5.56 | 5.57 | 5.56 | 5.63 | 5.69 | 5.41 | 5.77 | 5.98 | 5.75 |
| 19 | | 5.51 | 5.70 | 5.86 | 5.69 | 5.58 | 5.78 | 5.99 | 5.67 | 5.52 | | | |
| 22 | | 5.99 | | 6.08 | 6.01 | 5.89 | 5.97 | 6.09 | 5.97 | 5.95 | | | |
| | | HD-60 | | | | LD-60 | | | | | | | |
| 1 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | | | | |
| 4 | 3.80 | 3.39 | 3.34 | 3.44 | 3.33 | 3.89 | 3.95 | 3.85 | 3.65 | | | | |
| 7 | 4.77 | 3.76 | 3.50 | 4.99 | 3.36 | 4.95 | 4.67 | 4.87 | 4.97 | | | | |
| 10 | 5.41 | 4.04 | 5.27 | 5.21 | 4.94 | 5.01 | 5.19 | 5.08 | 5.21 | | | | |
| 13 | | 5.07 | 5.38 | 5.29 | 5.50 | 5.28 | 5.32 | 5.14 | 5.32 | | | | |
| 16 | | 5.66 | 5.59 | 5.71 | 5.95 | 5.34 | 5.44 | 5.59 | 5.56 | | | | |
| 19 | | 5.87 | 5.65 | 5.73 | 5.97 | 5.37 | 5.67 | 5.74 | 5.70 | | | | |
| 22 | | 5.98 | 5.84 | 5.90 | 6.08 | 5.74 | 5.96 | 5.89 | 5.99 | | | | |
| 25 | | | | | | 6.04 | 6.01 | 6.02 | | | | | |
| | | HD-80 | | | | LD-80 | | | | | | | |
| 1 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | | | | |
| 4 | 3.80 | 3.38 | 3.42 | 3.33 | 3.43 | 3.65 | 3.39 | 3.47 | 3.35 | | | | |
| 7 | 4.77 | 4.29 | 3.53 | 3.47 | 3.59 | 3.85 | 3.72 | 3.82 | 3.47 | | | | |
| 10 | 5.41 | 4.63 | 4.85 | 5.12 | 5.20 | 4.10 | 4.99 | 5.09 | 5.01 | | | | |
| 13 | | 4.93 | 5.28 | 5.48 | 5.44 | 4.28 | 5.09 | 5.34 | 5.14 | | | | |
| 16 | | 5.42 | 5.73 | 5.61 | 5.73 | 4.38 | 5.28 | 5.64 | 5.55 | | | | |
| 19 | | 5.57 | 6.03 | 5.73 | 5.95 | 4.65 | 5.77 | 5.88 | 5.93 | | | | |
| 22 | | 5.72 | 6.08 | 5.96 | 6.10 | 5.06 | 5.84 | 5.91 | 5.99 | | | | |
| 25 | | 5.96 | | | | 5.51 | | | | | | | |
| 28 | | | | | | 5.91 | | | | | | | |

Table 4.19 Average values of pH in different films under brick & sand storage conditions

| Duration (days) | Control | Different treatments in films | | | | | | | | | | | |
|--------------------|---------|-------------------------------|------|------|------|--------------|------|------|------|-------------|------|------|------|
| | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 |
| 4 | 3.48 | 3.40 | 4.08 | 3.77 | 3.39 | 3.43 | 4.00 | 3.65 | 3.27 | 3.33 | 3.70 | 3.43 | 3.24 |
| 7 | 5.15 | 4.53 | 4.22 | 3.62 | 3.57 | 4.02 | 5.03 | 5.03 | 5.38 | 3.83 | 4.95 | 4.72 | 4.89 |
| 10 | 5.55 | 5.29 | 5.33 | 5.34 | 5.26 | 5.19 | 5.32 | 5.13 | 5.46 | 4.97 | 5.11 | 5.11 | 5.16 |
| 13 | | 5.46 | 5.42 | 5.38 | 5.66 | 5.29 | 5.41 | 5.52 | 5.69 | 5.32 | 5.55 | 5.43 | 5.47 |
| 16 | | 5.58 | 5.76 | 5.61 | 5.79 | 5.45 | 5.61 | 5.62 | 5.76 | 5.41 | 5.69 | 5.55 | 5.71 |
| 19 | | 5.67 | 5.81 | 5.71 | 5.85 | 5.69 | 5.89 | 5.70 | 5.78 | 5.56 | 5.81 | 5.81 | 5.90 |
| 22 | | 5.94 | 5.93 | 5.84 | 5.95 | 5.90 | 5.96 | 5.86 | 5.94 | 5.98 | 6.13 | 6.10 | 6.16 |
| 25 | | | | | | 6.01 | | | | 6.01 | | | |
| | | HD-60 | | | | LD-60 | | | | | | | |
| 1 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | | | | |
| 4 | 3.48 | 3.39 | 3.46 | 3.75 | 3.58 | 3.50 | 3.31 | 3.37 | 3.40 | | | | |
| 7 | 5.15 | 4.46 | 3.77 | 4.47 | 3.88 | 4.83 | 4.52 | 4.69 | 5.10 | | | | |
| 10 | 5.55 | 5.17 | 5.18 | 4.95 | 5.32 | 5.01 | 4.83 | 5.04 | 5.26 | | | | |
| 13 | | 5.36 | 5.21 | 5.20 | 5.52 | 5.20 | 5.27 | 5.38 | 5.64 | | | | |
| 16 | | 5.43 | 5.66 | 5.67 | 5.78 | 5.27 | 5.34 | 5.54 | 5.72 | | | | |
| 19 | | 5.59 | 5.96 | 5.92 | 5.82 | 5.39 | 5.58 | 5.67 | 5.79 | | | | |
| 22 | | 5.98 | 6.01 | 5.98 | 5.91 | 5.61 | 5.69 | 5.81 | 5.96 | | | | |
| 25 | | 6.02 | | | | 5.89 | 5.82 | 5.84 | | | | | |
| 28 | | | | | | 6.01 | | | | | | | |
| | | HD-80 | | | | LD-80 | | | | | | | |
| 1 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | | | | |
| 4 | 3.48 | 4.10 | 3.69 | 3.97 | 3.77 | 3.51 | 3.95 | 3.64 | 3.98 | | | | |
| 7 | 5.15 | 4.44 | 5.03 | 5.13 | 5.21 | 3.70 | 4.81 | 4.19 | 4.89 | | | | |
| 10 | 5.55 | 5.09 | 5.28 | 5.40 | 5.33 | 3.93 | 5.06 | 5.20 | 5.13 | | | | |
| 13 | | 5.35 | 5.37 | 5.45 | 5.52 | 4.46 | 5.26 | 5.42 | 5.22 | | | | |
| 16 | | 5.41 | 5.42 | 5.83 | 5.79 | 4.75 | 5.39 | 5.66 | 5.52 | | | | |
| 19 | | 5.60 | 5.76 | 5.84 | 5.98 | 5.03 | 5.63 | 5.86 | 5.67 | | | | |
| 22 | | 5.78 | 5.83 | 5.96 | 5.99 | 5.19 | 5.71 | 5.96 | 5.88 | | | | |
| 25 | | 5.91 | | | | 5.57 | 5.92 | 5.98 | | | | | |
| 28 | | | | | | 5.77 | | | | | | | |

Table 4.20 Average values of pH in different films under cold storage conditions

| Duration (days) | Control T | Different treatments in films | | | | | |
|--------------------|--------------|-------------------------------|------|-------|------|------|------|
| | | HD-40 | | LD-40 | | S-60 | |
| | | T0 | T1 | T0 | T1 | T0 | T1 |
| 1 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 |
| 15 | 3.60 | 3.78 | 3.98 | 3.78 | 3.92 | 3.40 | 3.42 |
| 22 | 4.34 | 4.18 | 4.40 | 4.04 | 4.16 | 4.16 | 4.22 |
| 31 | | 4.55 | 4.90 | 4.75 | 4.99 | 4.64 | 4.94 |
| | | HD-60 | | LD-60 | | | |
| 1 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | | |
| 15 | 3.60 | 4.01 | 4.03 | 3.85 | 4.09 | | |
| 22 | 4.34 | 4.08 | 4.37 | 4.48 | 4.62 | | |
| 31 | | 5.03 | 5.23 | 4.99 | 5.16 | | |
| | | HD-80 | | LD-80 | | | |
| 1 | 3.22 | 3.22 | 3.22 | 3.22 | 3.22 | | |
| 15 | 3.60 | 3.64 | 3.84 | 3.54 | 4.15 | | |
| 22 | 4.34 | 4.21 | 4.41 | 4.36 | 4.38 | | |
| 31 | | 5.22 | 5.27 | 5.11 | 5.26 | | |

in cold store had similar trend but recorded lower pH values than other two types of films. The important development in cold store was that pH remained quite low from threshold limit in both perforated and non-perforated treatment even after one month of storage, may be low temperature had hindered the ripening process and colour remained green. These findings are in agreement with the results reported by Leley *et al.* (1943), Soule and Harding (1956), Joshi and Roy (1986), Sahni and Khurdiya (1989), Gonzalez *et al.* (1997).

4.2.5.1 Statistical Analysis: The result of statistical analysis for three selected films are presented in Table 4.21. The store means were found to be 5.11 and 5.03 which indicated that pH in RT was slightly higher than B&S store. But its effect was

insignificant. A comparison of film means showed that LD-80 had the lowest value among three selected films with a pH of 4.82, 5.27, 5.55 and 5.69 at the end of 10,

Table 4.21 Statistical analysis of pH in mangoes

| Duration (days) | Treat. combination means | | | Factor means | | | CD (5%) | | | |
|----------------------|-------------------------------|------|------|--------------|------|---------------------|------------------------------------|----|-------|----|
| | T | To | T1-3 | FI | Tt | St | Tt | FI | TtXFI | St |
| 10 | 5.48 | 5.01 | 5.10 | 5.08 | 4.68 | 5.11 | 0.164 0.142 0.285 (0.29). | | | |
| | | 4.02 | 5.08 | 4.82 | 5.10 | 5.03 | | | | |
| | | 5.01 | 5.28 | 5.21 | 5.17 | | | | | |
| 16 | | 5.31 | 5.53 | 5.48 | 5.09 | | 0.168 0.146 0.291 | | | |
| | | 4.57 | 5.51 | 5.27 | 5.49 | | | | | |
| | | 5.41 | 5.74 | 5.66 | 5.66 | | | | | |
| | | | | | 5.64 | | | | | |
| 19 | | 5.38 | 5.70 | 5.61 | 5.11 | | 0.224 - 0.317 | | | |
| | | 4.84 | 5.79 | 5.55 | 5.66 | | | | | |
| | | | | | 5.79 | | | | | |
| | | | | | 5.77 | | | | | |
| 22 | | 5.68 | 5.89 | 5.83 | 5.78 | | 0.145 0.102 0.204 | | | |
| | | 5.13 | 5.89 | 5.69 | 5.80 | | | | | |
| | | | | | 5.89 | | | | | |
| | | | | | 5.96 | | | | | |
| NOTE: | Tt: Treatment(To,T1,T2,T3) | | | | | St: Store (RT,B&S) | | | | |
| | FI: Film (LD-60,LD-80,S-60) | | | | | TtxFI: Interaction | | | | |

16, 19 & 22nd day of storage, respectively. The difference in film means reduced at the later stage. This is verified by the CD (5 percent) values of 0.145 & 0.102 at initial and later stages. The treatment means showed that non-perforated films had significantly lower pH as compared to perforated but level of perforation had insignificant effect on pH values. The treatment means for non-perforated films were 4.68, 5.09, 5.11 & 5.78 after respective period of storage. The effect of treatment increased with the duration of storage except in the last stage where pH crossed the threshold limit. Although film & treatments had individual and significant effect but

interaction between them had more effect. Thus the statistical results more or less verified the experimental findings.

4.2.6 Decay

The decay in fruits is represented by percent rotting. The average values of rotting (percent) in different treatments of all films and storage environments are presented in Table 4.22-4.24 and trends of change in rotting are shown in Fig.4.15-4.17.

A perusal of the Table 4.22 showed that rotting was very low (8.5 percent) in control fruits kept under RT storage conditions. This was because fruits were mostly spoiled after excessive shrinkage. Similar results were observed by Kalra *et al.* (1988). In film wrapped treatments, rotting was very low in non-perforated treatments (Fig.4.15) as compared with perforated especially in LDPE and S-60 films. The rotting increased with the level of perforations in all the films. These results corroborate the findings of Singh and Singh (1992) which reported that control fruits were in direct contact with air and side by side they were readily exposed to atmospheric pathogens which might have caused the spoilage. Antiseptic action might have inspired for less spoilage in wrapped fruits and due to its action as a barrier between fruits skin and atmosphere. Wrapping played important role in preventing infection of micro-organisms and fungal lesions in fruits (Singh *et al.* 1967). The thicknesses of the films had no definite effect on rotting in non-perforated HDPE films while it decreased with thickness in LDPE film. In perforated treatments, rotting decreased with thickness and this variation was more visible in LDPE films. The rotting after 19th day of storage was 31.23, 27.21, 30.91 and 55.80, 49.24, 42.87

percent in non-perforated and perforated treatments and respective thicknesses of HDPE films. While in LDPE films, rotting was 17.92, 9.29, 9.59 and 48.60, 24.67, 19.60 percent in non-perforated and perforated treatments and respective thicknesses of the film. The S-60 film had 59.34 and 100 percent rotting in respective treatments.

In all treatments of B&S store, spoilage was mainly by rotting (Fig.4.16) irrespective of type of film, thicknesses and level of perforations. In non-wrapped mangoes, the rotting was very rapid in the last stages which can be gauged from the fact that about 86 per cent of mangoes got spoiled in last three days (7-10th). There was no significant difference in rotting between perforated treatments of HDPE films especially at higher film thicknesses. Non-perforated treatments, on the contrary, had distinctive edge in rotting over perforated treatments irrespective of thickness of the film. The rotting in non-perforated and perforated treatments of HDPE films after 19th day of storage was 31.92, 36.85, 43.66 and 54.95, 37.57, 40.07 per cent in respective thicknesses of the films. The rotting in LDPE films was 35.29, 6.37, 6.47 and 50.72, 41.79, 35.29 per cent in respective treatments. The S-60 film had 36.12 and 58.62 per cent rotting in non-perforated and perforated treatments respectively.

Similar trends were found in cold store (Fig.4.17) but rotting (percent) was comparatively slow and low than RT & B&S storage in all films, thicknesses and treatments. The low and delayed spoilage in cold store may be due to delayed ripening (Saucedo *et al.*, 1978; Mann and Singh, 1976; Joshi and Roy, 1986). However, the rotting at lowest gauge film (40 gauge) in both LDPE and HDPE was comparable in all the three storage environments. Comparing non-wrapped

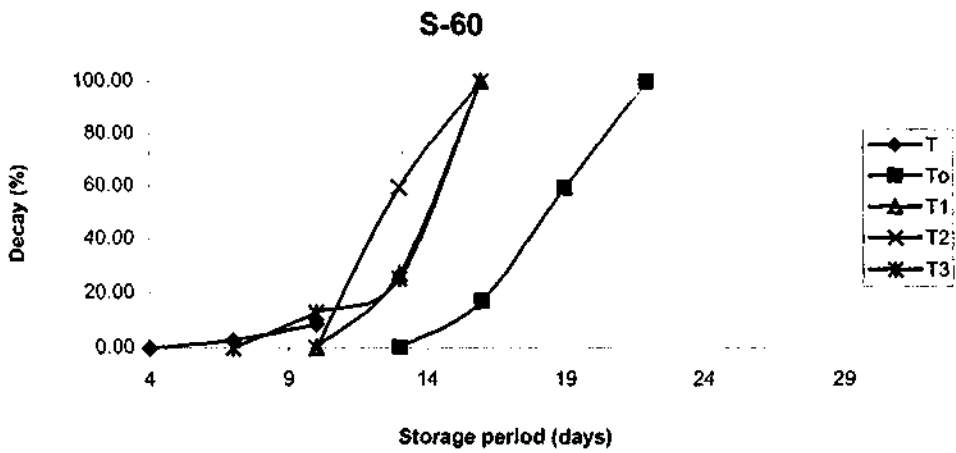
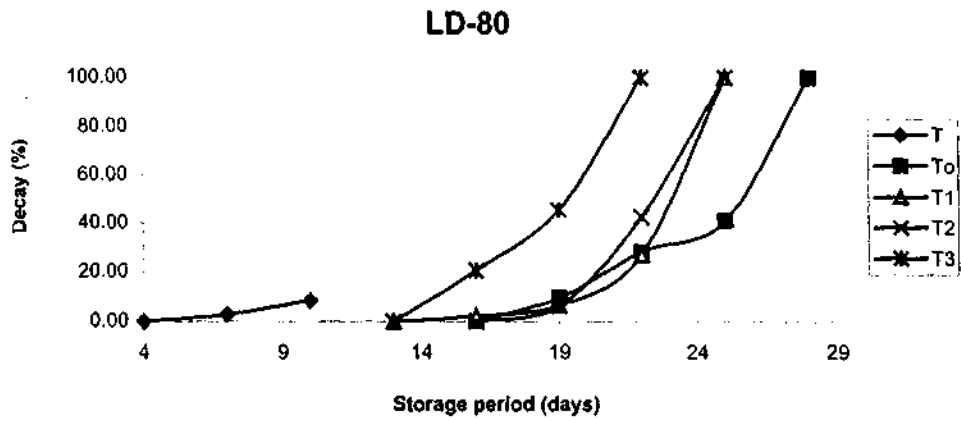
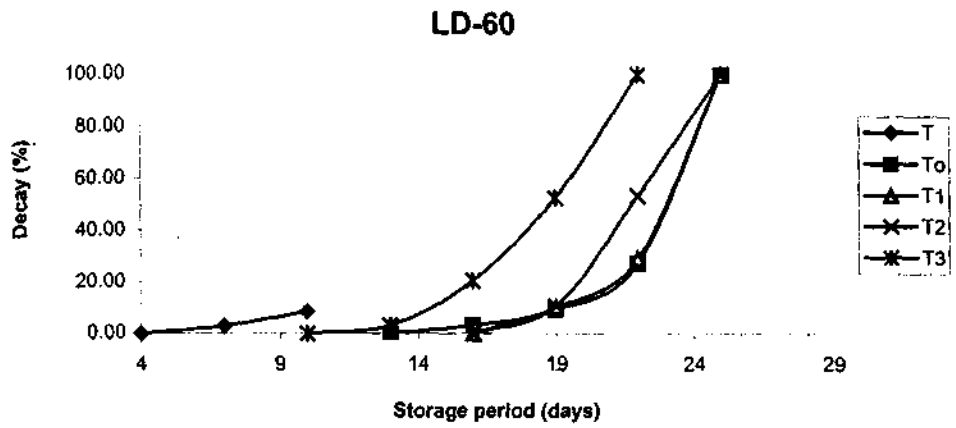


Fig 4.15 Decay under RT storage conditions

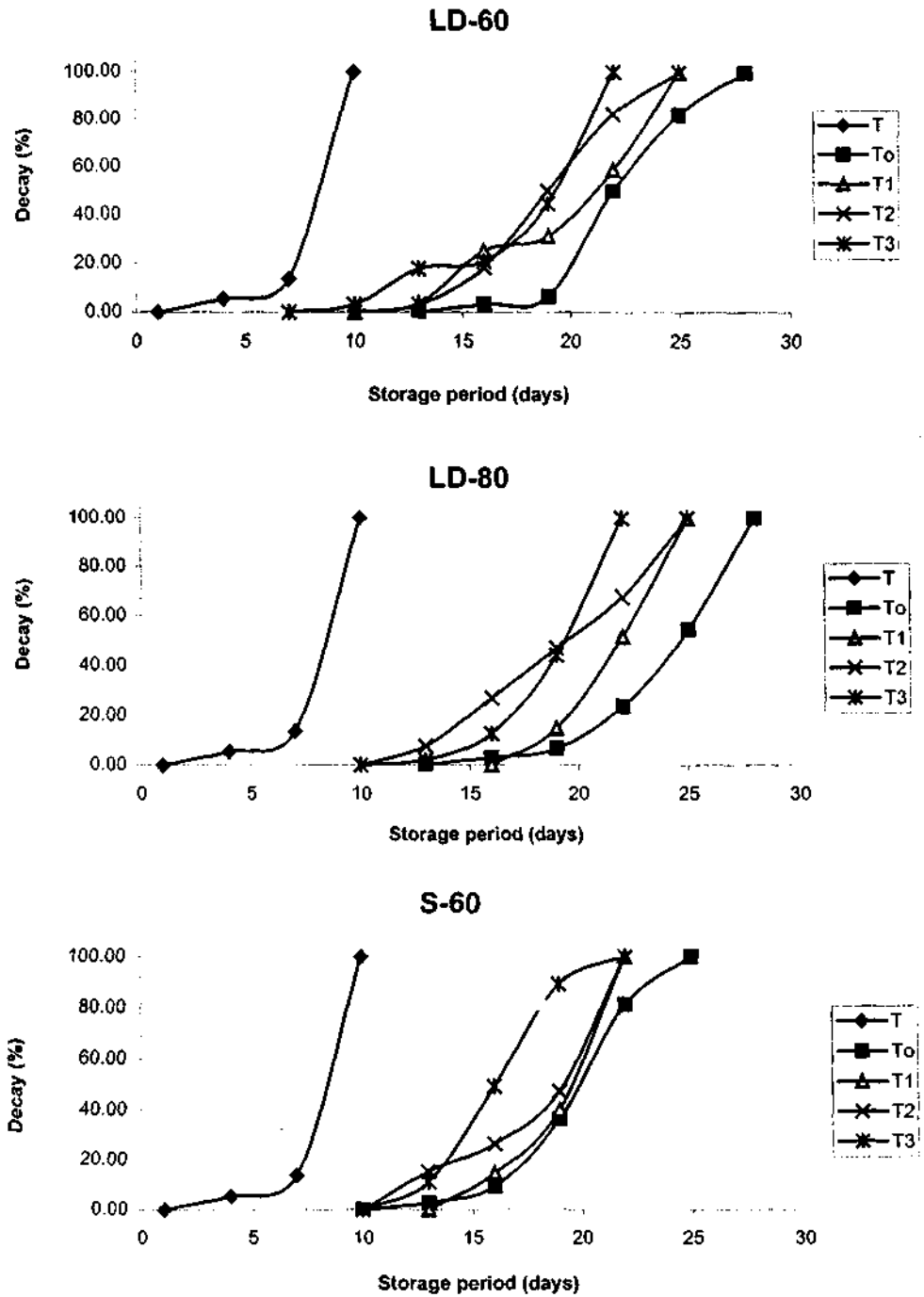


Fig 4.16 Decay under B&S storage conditions

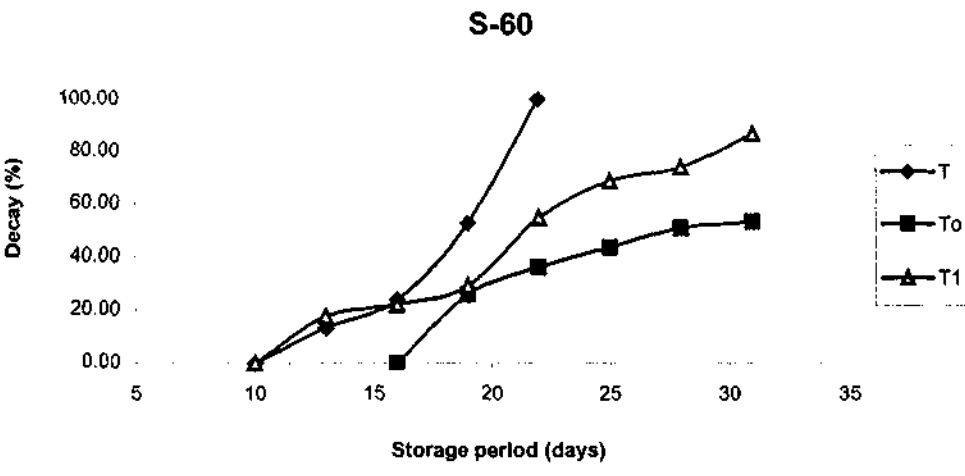
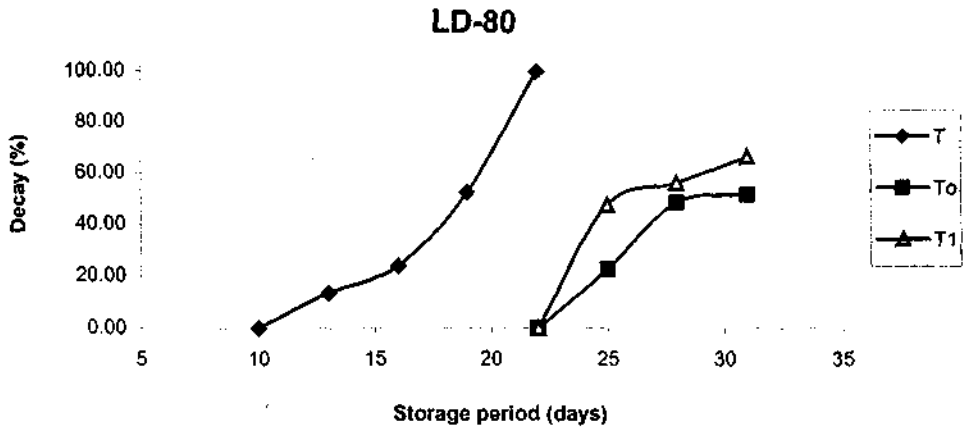
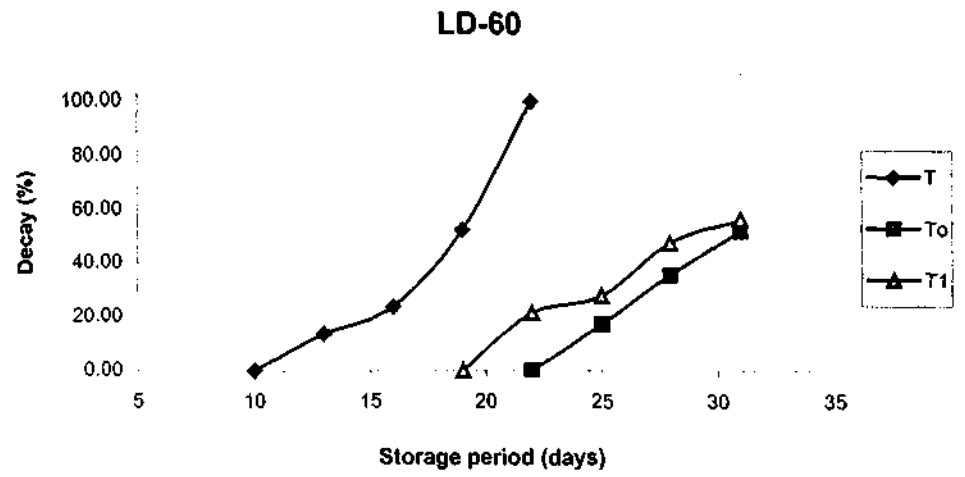


Fig 4.17 Decay under cold storage conditions

Table 4.22 Average values of decay (%) in different films under room temperature storage conditions

| Duration (days) | Control T | Different treatments in films | | | | | | | | | | | |
|--------------------|--------------|-------------------------------|--------|--------|--------|--------------|--------|--------|--------|-------------|--------|--------|--------|
| | | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | 2.85 | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | 8.50 | - | - | - | - | - | - | - | - | - | - | - | 12.63 |
| 13 | | 5.61 | 3.62 | 7.18 | 3.35 | 2.45 | 2.87 | 7.16 | 6.23 | - | 27.04 | 59.51 | 25.25 |
| 16 | | 11.05 | 17.91 | 14.33 | 10.17 | 4.87 | 8.34 | 15.06 | 34.65 | 16.93 | 100.00 | 100.00 | 100.00 |
| 19 | | 31.23 | 37.84 | 56.51 | 61.06 | 17.92 | 27.12 | 51.34 | 67.34 | 59.34 | | | |
| 22 | | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | | | |
| | | HD-60 | | | | LD-60 | | | | | | | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | 2.85 | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | 8.50 | - | - | - | - | - | - | - | 0.00 | - | - | - | - |
| 13 | | - | - | - | 6.22 | - | - | - | 3.25 | - | - | - | - |
| 16 | | 16.04 | 11.52 | 20.38 | 37.06 | 3.21 | - | - | 20.64 | - | - | - | - |
| 19 | | 27.71 | 33.20 | 55.10 | 59.42 | 9.29 | 10.28 | 10.82 | 52.90 | - | - | - | - |
| 22 | | 100.00 | 100.00 | 100.00 | 100.00 | 27.42 | 29.30 | 53.77 | 100.00 | - | - | - | - |
| 25 | | | | | | 100.00 | 100.00 | 100.00 | | | | | |
| | | HD-80 | | | | LD-80 | | | | | | | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | 2.85 | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | 8.50 | - | - | - | - | - | - | - | - | - | - | - | - |
| 13 | | - | 6.75 | - | 10.25 | - | - | - | - | - | - | - | - |
| 16 | | 7.19 | 24.14 | 12.31 | 23.92 | - | 2.21 | - | 20.66 | - | - | - | - |
| 19 | | 30.91 | 33.02 | 46.43 | 49.17 | 9.59 | 6.61 | 6.35 | 45.83 | - | - | - | - |
| 22 | | 65.95 | 100.00 | 100.00 | 100.00 | 28.46 | 27.21 | 42.88 | 100.00 | - | - | - | - |
| 25 | | 100.00 | | | | 41.44 | 100.00 | 100.00 | | | | | |
| 28 | | | | | | 100.00 | | | | | | | |

Table 4.23 Average values of decay (%) in different films under brick&sand storage conditions

| Duration (days) | Control | Different treatments in films | | | | | | | | | | | |
|--------------------|---------|-------------------------------|--------|--------|--------|---------------|--------|--------|--------|-------------|--------|--------|--------|
| | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | 5.41 | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | 13.60 | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | 100.00 | - | - | - | 2.11 | - | - | - | 2.50 | - | - | - | - |
| 13 | | 7.91 | 5.12 | 5.32 | 13.43 | 6.80 | 7.18 | 6.28 | 17.40 | 2.79 | - | 15.18 | 11.11 |
| 16 | | 13.31 | 23.33 | 21.71 | 57.72 | 12.83 | 15.09 | 17.23 | 36.18 | 9.32 | 14.48 | 26.35 | 49.01 |
| 19 | | 31.92 | 45.87 | 42.06 | 76.91 | 35.29 | 43.54 | 46.80 | 61.81 | 36.12 | 39.86 | 47.06 | 88.95 |
| 22 | | 100.00 | 100.00 | 100.00 | 100.00 | 64.66 | 100.00 | 100.00 | 100.00 | 81.24 | 100.00 | 100.00 | 100.00 |
| 25 | | | | | | 100.00 | | | | 100.00 | | | |
| | | HD-60 | | | | LD-60 | | | | | | | |
| 1 | - | - | - | - | - | - | - | - | - | | | | |
| 4 | 5.41 | - | - | - | - | - | - | - | - | | | | |
| 7 | 13.60 | - | - | - | - | - | - | - | - | | | | |
| 10 | 100.00 | - | - | - | - | - | - | - | 3.09 | | | | |
| 13 | | 2.67 | 4.30 | 4.63 | 10.03 | - | 3.53 | 2.98 | 17.79 | | | | |
| 16 | | 14.24 | 13.44 | 14.74 | 22.14 | 3.23 | 25.01 | 18.28 | 20.79 | | | | |
| 19 | | 36.85 | 31.03 | 39.73 | 41.94 | 6.37 | 31.10 | 49.81 | 44.46 | | | | |
| 22 | | 56.88 | 100.00 | 100.00 | 100.00 | 49.75 | 58.38 | 82.20 | 100.00 | | | | |
| 25 | | 100.00 | | | | 82.07 | 100.00 | 100.00 | | | | | |
| 28 | | | | | | 100.00 | | | | | | | |
| | | HD-80 | | | | LD--80 | | | | | | | |
| 1 | - | - | - | - | - | - | - | - | - | | | | |
| 4 | 5.41 | - | - | - | - | - | - | - | - | | | | |
| 7 | 13.60 | - | - | - | - | - | - | - | - | | | | |
| 10 | 100.00 | - | - | 2.64 | 2.57 | - | - | - | - | | | | |
| 13 | | - | 8.99 | 12.64 | 11.95 | - | - | 7.61 | 2.14 | | | | |
| 16 | | 12.15 | 18.60 | 23.76 | 21.92 | 3.01 | - | 26.83 | 12.63 | | | | |
| 19 | | 43.66 | 37.89 | 38.49 | 43.83 | 6.47 | 14.66 | 46.97 | 44.13 | | | | |
| 22 | | 47.66 | 100.00 | 100.00 | 100.00 | 23.58 | 51.63 | 67.59 | 100.00 | | | | |
| 25 | | 100.01 | | | | 54.51 | 100.00 | 100.00 | | | | | |
| 28 | | | | | | 100.00 | | | | | | | |

Table 4.24 Average values of decay (%) in different films under cold storage conditions

| Duration (days) | Control T | Different treatments in films | | | | | |
|--------------------|--------------|-------------------------------|--------|--------------|--------|-------------|-------|
| | | T0 | T1 | T0 | T1 | T0 | T1 |
| | | HD-40 | | LD-40 | | S-60 | |
| 10 | - | - | - | - | - | - | - |
| 13 | 13.54 | - | - | - | - | - | 17.75 |
| 16 | 23.75 | - | 26.80 | - | - | - | 21.98 |
| 19 | 52.47 | 24.98 | 50.52 | 28.53 | 31.23 | 25.69 | 28.98 |
| 22 | 100.00 | 35.66 | 74.50 | 41.26 | 46.79 | 36.02 | 54.44 |
| 25 | | 47.34 | 89.97 | 52.99 | 65.39 | 43.36 | 68.67 |
| 28 | | 63.02 | 100.00 | 63.72 | 88.21 | 50.73 | 73.91 |
| 31 | | 75.70 | | 71.46 | 100.00 | 53.06 | 86.82 |
| | | HD-60 | | | | | |
| 10 | - | - | - | - | - | | |
| 13 | 13.54 | - | - | - | - | | |
| 16 | 23.75 | - | - | - | - | | |
| 19 | 52.47 | - | 23.00 | - | - | | |
| 22 | 100.00 | 25.66 | 34.34 | - | 21.35 | | |
| 25 | | 34.59 | 47.71 | 17.27 | 27.86 | | |
| 28 | | 47.53 | 59.07 | 35.66 | 47.73 | | |
| 31 | | 57.59 | 72.43 | 52.17 | 56.52 | | |
| | | HD-80 | | | | | |
| 10 | - | - | - | - | - | | |
| 13 | 13.54 | - | - | - | - | | |
| 16 | 23.75 | - | - | - | - | | |
| 19 | 52.47 | 26.20 | 49.33 | - | - | | |
| 22 | 100.00 | 31.56 | 52.91 | - | - | | |
| 25 | | 39.93 | 57.07 | 22.55 | 47.69 | | |
| 28 | | 47.79 | 64.59 | 48.53 | 56.34 | | |
| 31 | | 55.66 | 69.68 | 51.76 | 66.67 | | |

treatments in all the three stores, it was observed that rotting started in 7, 4 & 13th day of storage in respective stores. While in film wrapped treatments, it started mainly after 13 and 19-22nd day of storage in RT & B&S store and cold store, respectively. The non-perforated LDPE film in general and 80/60 gauge thicknesses in particular had bulk of the rotting started in 25-28th day and 22nd day in refrigerated and non-refrigerated storage respectively. Stem end rot was the major disease in film wrapped treatments. Same disease was observed by Rameshwar *et al.* (1979b). All above results are in conformity with the observations of Reddy and Raju (1988), Hudder *et al.* (1995), Genzalez *et al.* (1997), Kalra *et al.* (1988), Saucedo *et al.* (1978), Mann and Singh (1976) and Rameshwar *et al.* (1979b).

4.2.6.1 Statistical Analysis: The results of statistical analysis are presented in

Table 4.25 Statistical analysis of decay (%) in mangoes.

| Duration (days) | Treat. combination means | | | Factor means | | | CD (5%) | | | |
|--------------------|--------------------------|-----------------------------|-------|--------------|-------|--------------------|---------|-------|------|----|
| | T | To | T1-3 | FI | Tt | St | Tt | FI | TxFI | St |
| 10 | 54.25 | 0.00 | 1.37 | 1.03 | 0.00 | - | - | - | - | - |
| | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | |
| | | 0.00 | 2.10 | 1.58 | 0.00 | 3.47 | | | | |
| 16 | | 3.22 | 14.12 | 11.40 | 5.95 | | - | 28.84 | - | - |
| | | 1.51 | 10.73 | 8.42 | 23.95 | | | | | |
| | | 13.13 | 64.98 | 52.01 | 32.35 | 33.51 | | | | |
| 19 | | 8.83 | 33.23 | 27.13 | 7.93 | | 22.72 | - | - | - |
| | | 7.03 | 27.43 | 22.33 | 15.66 | | | | | |
| | | | | | 28.49 | 46.83 | | | | |
| 22 | | 33.59 | 70.61 | 61.35 | 28.55 | | 15.73 | - | - | - |
| | | 23.52 | 64.89 | 54.54 | 41.63 | | | | | |
| | | | | | 61.61 | 100.00 | | | | |
| NOTE: | | Tt: Treatment(To,T1,T2,T3) | | | | St: Store (RT,B&S) | | | | |
| | | FI: Film (LD-60,LD-80,S-60) | | | | TtxFI: Interaction | | | | |

Table 4.25. A perusal of the film means showed that LDPE films had low rotting than S-60 film. The film means for LD-80 & LD-60 films were 0, 8.42, 22.33, 54.54 and 1.03, 11.40, 27.13, 61.35 after 10, 16, 19, 22nd day of storage in respective films. The treatment means for non-perforated treatment were quite low compared with perforated treatments during entire period of storage. Again treatments with lowest level of perforations had lower treatment means in comparison with other two perforation levels which among themselves had more or less the same amount of rotting. The treatment means for non-perforated films were 0, 5.95, 7.93, 28.55 and average treatment means for perforated films were 1.16, 29.94, 30.33, 67.75 after respective period of storage. The CD (5 percent) values for film and treatments indicated that both the films and treatments had their individual effects at different times but their interaction effect was non-significant. The LD-80/60 with no perforation gave the lowest rotting loss. Thus, the experimental results were statistically verified.

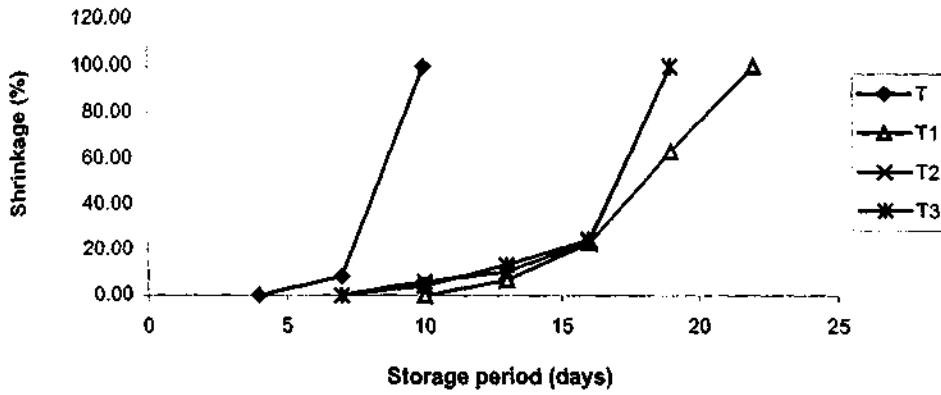
4.2.7 Shrinkage

The average values of percent shrinkage in different treatments of all films and storage environments are presented in Table 4.26 and the trends of change in shrinkage in top three films are shown in Fig.4.18.

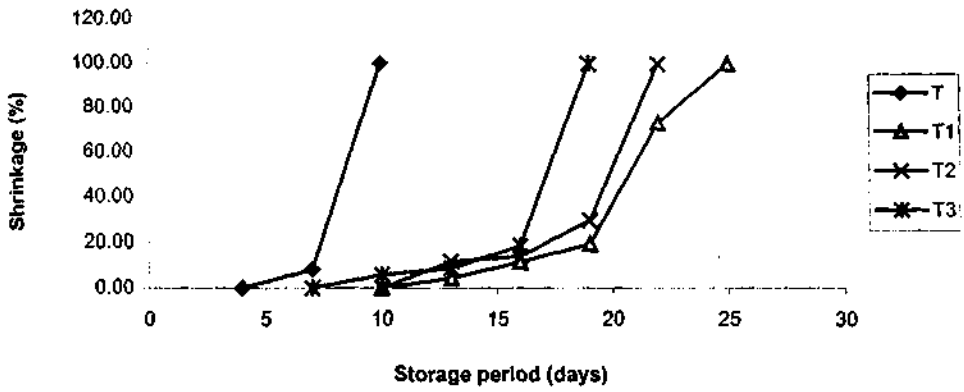
It is apparent from Fig.4.18 that shrinkage was extremely high in control fruits compared to film wrapped fruits and it increased with the duration of storage. High shrinkage in control fruits can be gauged from the fact that shrinkage first appeared on 7th day and within next two days all the lot got shrunken. No shrinkage was observed in non-perforated film wrapped treatments irrespective of thicknesses of

the films during entire period of storage. In perforated treatments, it increased with the level of perforation in all types of films and their thicknesses. Again the shrinkage decreased with the thicknesses of the film especially in treatments with top two levels of perforations (0.48, 0.78 percent). The difference in percent shrinkage in different treatments increased with period of storage. The above variations can be explained as : Since PLW has direct relationship with shrinkage, higher is PLW, higher is shrinkage (Joshi and Roy, 1986; Laxhminarayan *et al.* 1974). So, treatments with higher level of perforations had higher shrinkage. Singh and Narayana (1995) stated that higher level of RH inside film package maintained the gloss and prevented shriveling of fruits during storage. Gonzalez *et al.* (1977) stated that plastic covering plays an important role in preventing dehydration creating a saturated micro-atmosphere around the fruit. It was observed that mangoes stored at RT conditions suffered pronounced shrinkage and it increased with the level of perforations. Miller and Risse (1988) reported that the reduction in PLW by film wrapping resulted in retention of moisture which prolonged the onset of visible symptoms of senescence such as shriveling, wilting, aging, pulp softening and aided in the retention of fresh appearance of fruits. The shrinkage was first observed between 10-13th day of storage in perforated HDPE film treatments and the mangoes got shrunken between 19-22nd day. Similar trends and comparable values were observed in all treatments of LDPE film. The shrinkage in HDPE films treatments with lowest level of perforations after 16th day of storage was 25.58, 23.26 & 4.65 per cent in respective thicknesses of the film (40, 60, 80 gauge). The corresponding values in LDPE film treatments were 18.95, 23.06 and 11.63 per cent

LD-60



LD-80



S-60

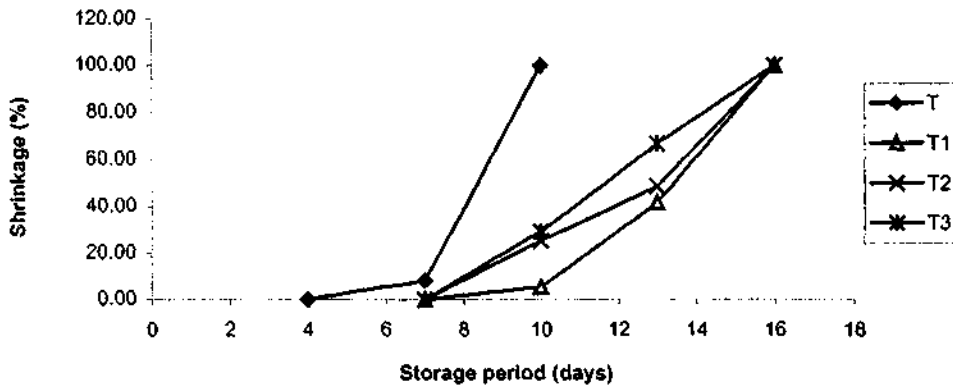


Fig 4.18 Shrinkage under RT storage conditions

Table 4.26 Average values of shrinkage(%) in different films under room temperature storage conditions

| Duration (days) | Control | Different treatments in films | | | | | | | | | | | |
|--------------------|---------|-------------------------------|--------|--------|--------|--------------|--------|--------|--------|-------------|--------|--------|--------|
| | T | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 | T0 | T1 | T2 | T3 |
| | | HD-40 | | | | LD-40 | | | | S-60 | | | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | 8.16 | - | - | - | 5.08 | - | - | - | - | - | - | - | - |
| 10 | 100.00 | - | 2.13 | 25.53 | 29.79 | - | - | 5.63 | 4.26 | - | 5.41 | 25.35 | 29.37 |
| 13 | | - | 11.11 | 40.00 | 55.56 | - | 14.41 | 15.56 | 17.78 | - | 41.67 | 48.57 | 66.67 |
| 16 | | - | 25.58 | 100.00 | 100.00 | - | 18.95 | 30.23 | 53.49 | - | 100.00 | 100.00 | 100.00 |
| 19 | | - | 100.00 | | | - | 100.00 | 100.00 | 100.00 | | | | |
| | | HD-60 | | | | LD-60 | | | | | | | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | 8.16 | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | 100.00 | - | - | 5.31 | 5.26 | - | - | 6.13 | 4.26 | - | - | - | - |
| 13 | | - | 6.67 | 11.71 | 15.56 | - | 6.67 | 10.49 | 13.33 | - | - | - | - |
| 16 | | - | 23.26 | 23.96 | 27.91 | - | 23.06 | 23.77 | 24.82 | - | - | - | - |
| 19 | | - | 58.54 | 100.00 | 100.00 | - | 63.39 | 100.00 | 100.00 | - | - | - | - |
| 22 | | - | 100.00 | | | - | 100.00 | | | - | - | - | - |
| | | HD-80 | | | | LD-80 | | | | | | | |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 7 | 8.16 | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | 100.00 | - | - | - | - | - | - | - | 5.78 | - | - | - | - |
| 13 | | - | - | 6.67 | 11.87 | - | 4.44 | 11.87 | 8.89 | - | - | - | - |
| 16 | | - | 4.65 | 23.49 | 27.91 | - | 11.63 | 13.95 | 18.60 | - | - | - | - |
| 19 | | - | 14.63 | 100.00 | 100.00 | - | 19.51 | 29.72 | 100.00 | - | - | - | - |
| 22 | | - | 100.00 | | | - | 73.13 | 100.00 | | - | - | - | - |
| 25 | | - | | | | - | 100.00 | | | - | - | - | - |

respectively. The shrinkage after 19th day of storage was found to be 100, 58.54 & 14.63 and 100, 63.39 and 19.51 in respective films and their thicknesses. These values are contrary to PLW in both the films. This was because the texture of HDPE film was hard and brittle which resulted in a prominent hole whereas the soft and pliable texture of LDPE film resulted in a zig zag hole. Moreover, in a perforated film, it is the perforation through which transmission of water vapour accounts for more than 95 percent of PLW which plays an important role in shrinkage rather than type of film and thicknesses. This is also explained by a very small difference in PLW values of perforated treatments in all the films in RT storage. As indicated by the percent shrinkage, these levels of perforations (0.26, 0.48, 0.78 percent) were found to be a bit higher. Thus, in order to take proper benefits of perforations, there is still a need to try at lower levels of perforations to eliminate the danger of shrinkage especially keeping in mind severe hot conditions (30-33°C) in our region. The S-60 film perforated treatments were worsted effected as far as shrinkage is concerned. This might be due to imperfect shrink wrapping in them making air flow through the package more free.

No shrinkage was found in B&S store and cold stores irrespective of whether mangoes were wrapped or non-wrapped. Similar findings were reported by Batagurki *et al.* (1995), Singh and Narayana (1995), Laxhminaranyana *et al.* (1974) and Gonzalez *et al.* (1997).

4.2.8 TSS/acid Ratio

The experiments conducted on modified atmosphere packaging and storage of mangoes revealed that the perforation levels tried (0.26, 0.48, 0.78 percent) were

too high which resulted in high PLW and subsequently shrinkage loss. Thus, taking into consideration, the performance of all seven films with respect to various physiological and quality parameters; top three films viz. LD-80, LD-60 and S-60 with three treatments (perforation level & N=0,2,4) were chosen for MA packaging and storage in three different environments. The TSS/acid ratio was estimated at 3 days interval and comparison was made. The average values of TSS/acid ratio in different treatments of all films and storage environments are presented in Table 4.27 and trends of change in TSS/acid ratio are shown in Fig.4.19-4.21.

It was observed (Fig.4.19) that there was a slow change in TSS/acid ratio in all treatments during initial period of 7 days, thereafter it changed at a slightly faster rate. In control fruits, a steep hike in TSS/acid ratio took place in last two days. In S-60 and LDPE film wrapped treatments on the other hand, a steady increase in TSS/acid ratio took place with lowest rate of change in non-perforated treatments and it increased with the level of perforations. This is because TSS/acid ratio is governed by acidity and TSS. The change in TSS is gradual. However, the change in acidity especially after onset of ripening, is rather steep which resulted in rise in TSS/acid ratio. Singh and Singh (1992) reported that maximum and rapid decrease in acidity was found in fruits with higher level of perforations, closely followed by next level of perforations and lowest degree of decrease was recorded in non-perforated treatments. The decrease in acidity was due to rapid utilization of acid in fruit pulp during respiration process. The film wrapped treatments having lower loss of moisture and delayed ripening might be responsible for minimizing changes in acidity. The S-60 film treatments in contrast to LDPE films did not differ much in their

TSS/acid ratio. This was because hole got sealed during heat shrink wrapping and perforation effect depended upon the efficiency of sealing. Moreover, holes were made manually which might have resulted in variable size and eventually affected the sealability. In LDPE films, holes were comparatively prominent. The non-perforated treatments resulted in too low value of TSS/acid ratio while treatments with 4 holes resulted in slightly higher ratio. It seemed that the treatments with 2 holes (perforation area = 5.4×10^{-3} percent) resulted in somewhat optimum value of TSS/acid ratio. The TSS/acid ratio was 115.67, 126.04, 195.90 after 22 days of storage in different treatments of S-60 films. The corresponding values in LDPE films were 38.84, 130.60, 186.57 and 62.03, 92.94, 138.06 in respective treatments. The level of citric acid, malic acid and ascorbic acid have been reported to decrease during ripening by 10, 40, 2.5 fold respectively (Pantastico, 1975). Thus, in our case malic acid could decrease from 1.61 to 0.04 percent and experimental results indicated the acidity change within these values. However, a review of cross-section of research implied that an acidity value of 0.13-0.2 percent is the threshold limit which indicates start of over ripening.

Similar trends were found in all treatments of B&S store (Fig.4.20) but TSS/acid ratio was slightly higher than RT store which might be due to higher TSS in B&S store than RT store. The TSS/acid ratio in different treatments of S-60, LD-60 and LD-80 films were 97.84, 136.82, 161.19 & 61.19, 156.72, 139.25 and 67.16, 85.20, 113.41 after 22nd day of storage respectively. The TSS/acid ratio in control fruits was lower in RT than B&S store. Here again treatments with two perforations seemed to give optimum TSS/acid ratio irrespective of type of film.

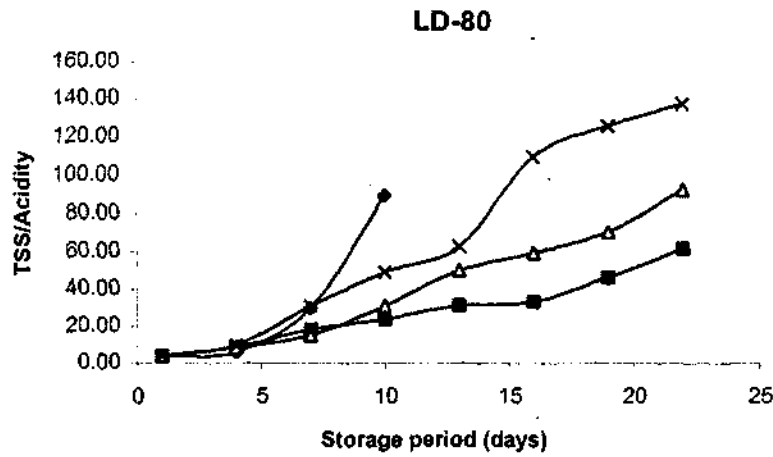
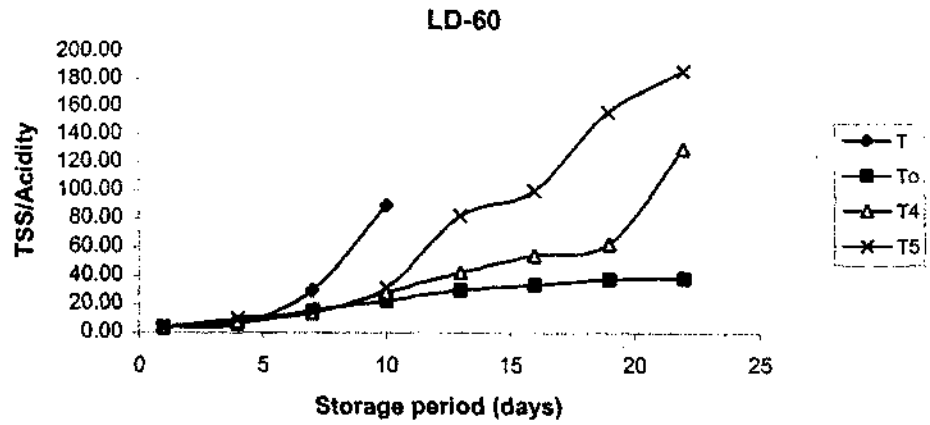
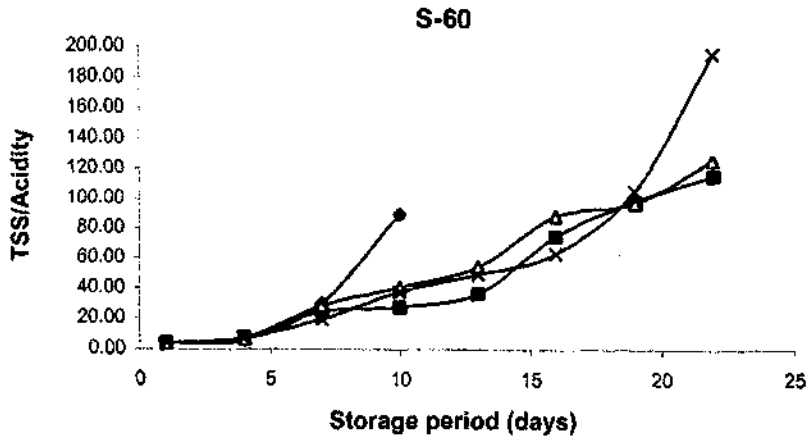


Fig 4.19 TSS/acidity ratio under RT storage conditions

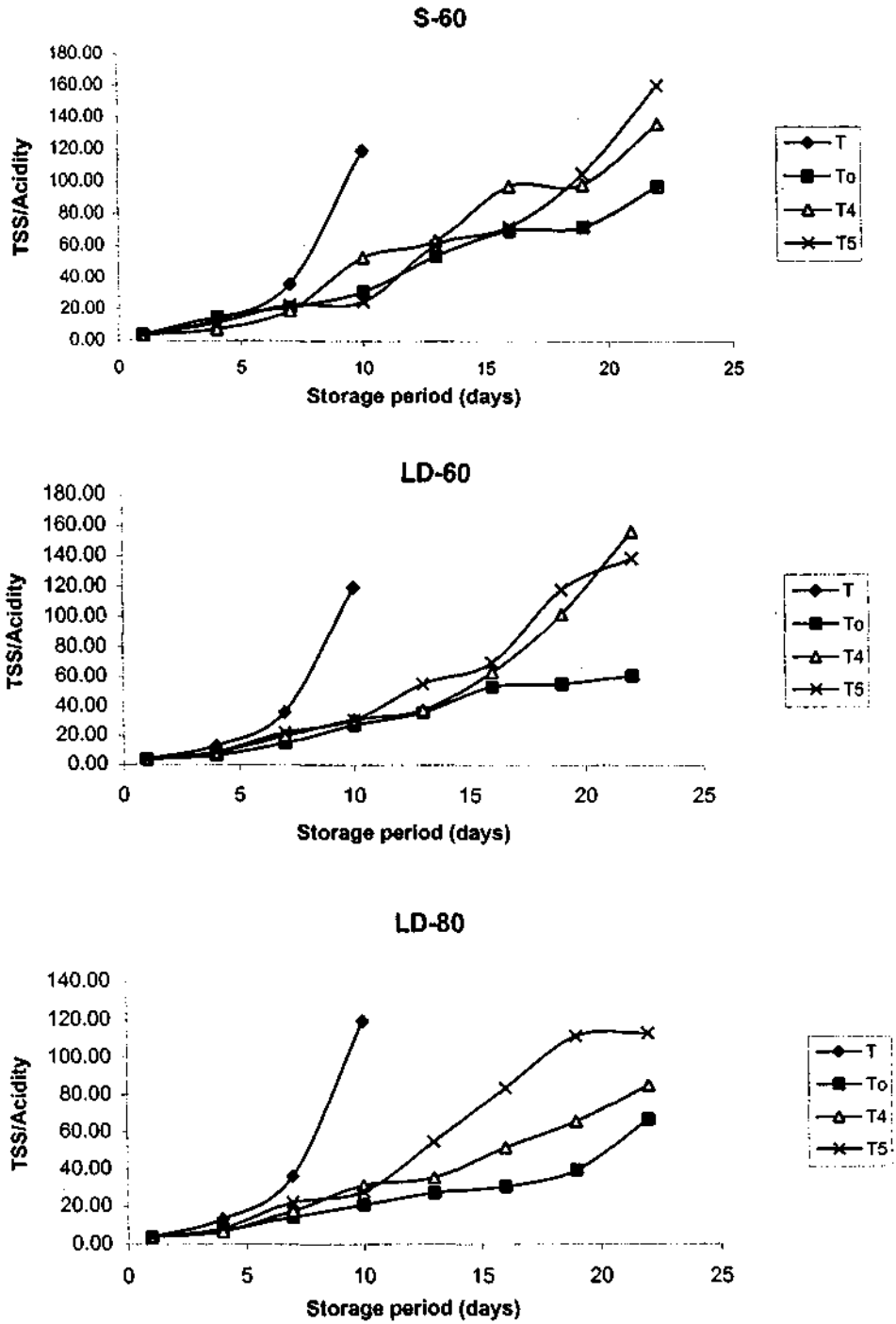


Fig 4.20 TSS/acidity ratio under B&S storage condition

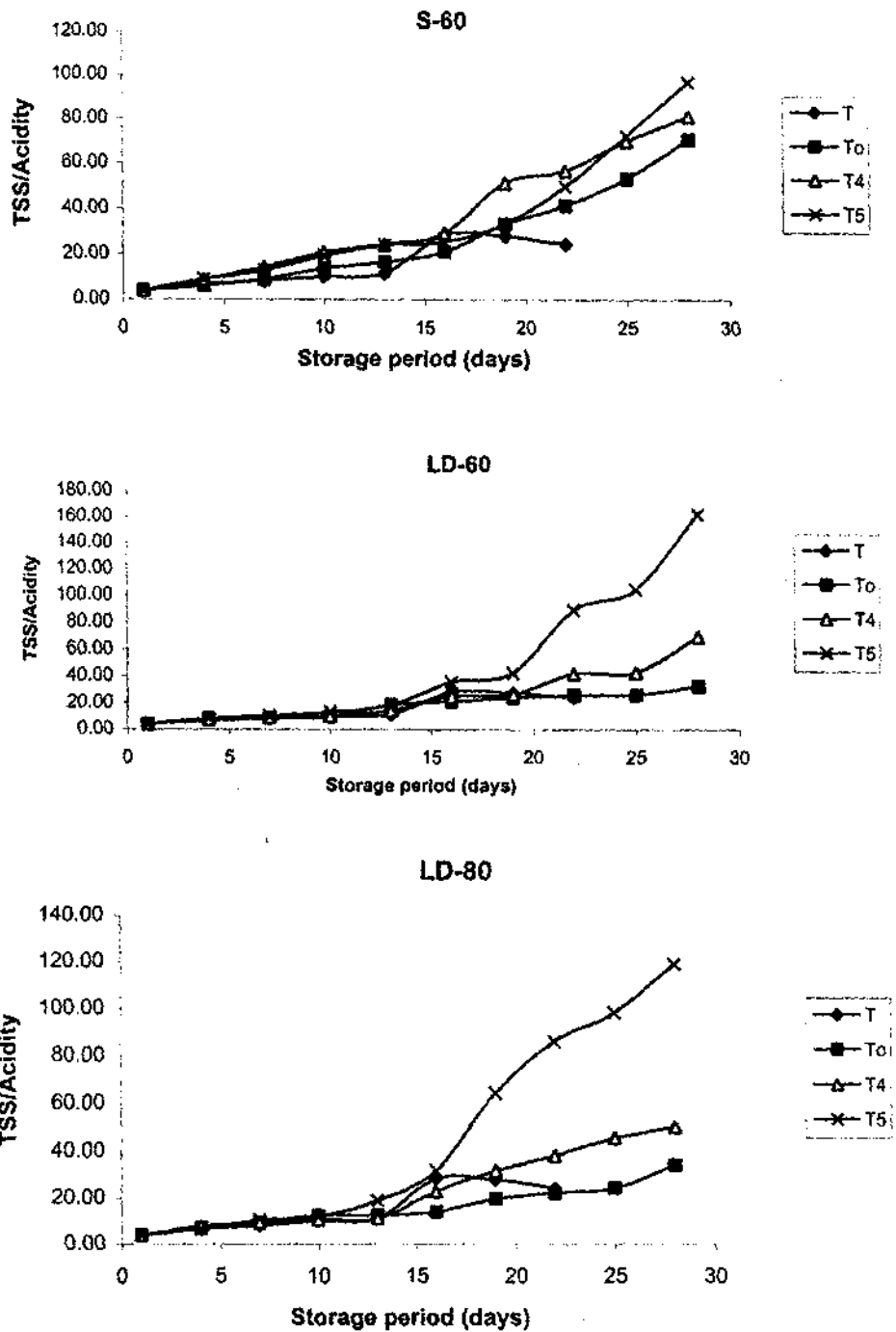


Fig 4.21 TSS/Acidity ratio under cold storage conditions

Table 4.27 Average values of TSS/acidity ratio in different films under different storage conditions

| Type of store | Duration (days) | Control T | S-60 | | | LD-60 | | | LD-80 | | |
|---------------|-----------------|-----------|--------|--------|--------|-------|--------|--------|-------|-------|--------|
| | | | T0 | T4 | T5 | T0 | T4 | T5 | T0 | T4 | T5 |
| RT | 1 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| | 4 | 6.09 | 7.71 | 6.89 | 7.38 | 6.31 | 7.72 | 9.94 | 8.84 | 8.52 | 9.79 |
| | 7 | 29.85 | 24.31 | 28.30 | 19.38 | 15.74 | 13.98 | 14.68 | 18.15 | 15.05 | 30.76 |
| | 10 | 89.55 | 27.40 | 40.56 | 37.31 | 22.60 | 28.27 | 31.56 | 23.92 | 31.05 | 49.25 |
| | 13 | | 36.42 | 54.01 | 49.04 | 30.09 | 42.55 | 82.09 | 31.30 | 50.11 | 62.97 |
| | 16 | | 74.63 | 88.20 | 63.18 | 33.85 | 54.58 | 100.33 | 33.58 | 59.70 | 109.89 |
| | 19 | | 98.51 | 97.01 | 105.41 | 37.70 | 62.69 | 156.72 | 46.64 | 70.65 | 126.04 |
| | 22 | | 115.67 | 126.04 | 195.90 | 38.84 | 130.60 | 186.57 | 62.03 | 92.94 | 138.06 |
| B&S | 1 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| | 4 | 13.16 | 14.97 | 7.35 | 11.26 | 6.55 | 8.44 | 8.89 | 7.04 | 6.75 | 8.28 |
| | 7 | 36.32 | 21.46 | 19.34 | 22.78 | 15.01 | 19.84 | 22.39 | 14.52 | 17.74 | 22.19 |
| | 10 | 119.54 | 31.25 | 52.95 | 24.88 | 27.44 | 31.25 | 30.99 | 20.83 | 31.35 | 27.88 |
| | 13 | | 53.90 | 63.65 | 60.59 | 36.17 | 37.79 | 55.31 | 27.26 | 35.51 | 54.84 |
| | 16 | | 70.15 | 97.69 | 72.49 | 53.54 | 63.43 | 70.10 | 30.76 | 51.88 | 83.78 |
| | 19 | | 72.33 | 98.67 | 105.41 | 55.31 | 101.99 | 118.25 | 39.52 | 65.76 | 111.53 |
| | 22 | | 97.84 | 136.82 | 161.19 | 61.19 | 156.72 | 139.30 | 67.16 | 85.20 | 113.41 |
| CS | 1 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 | 3.98 |
| | 4 | 6.65 | 6.08 | 8.71 | 8.77 | 7.79 | 7.64 | 8.31 | 7.23 | 7.95 | 6.74 |
| | 7 | 8.17 | 8.75 | 14.10 | 12.75 | 8.78 | 9.67 | 10.27 | 9.48 | 9.44 | 10.78 |
| | 10 | 10.07 | 13.75 | 20.73 | 19.26 | 9.79 | 10.24 | 13.23 | 12.40 | 10.68 | 12.01 |
| | 13 | 11.57 | 16.44 | 24.30 | 23.92 | 18.81 | 14.56 | 18.66 | 12.85 | 11.29 | 19.07 |
| | 16 | 28.49 | 21.17 | 29.25 | 25.33 | 21.17 | 25.33 | 35.88 | 14.13 | 23.13 | 31.91 |
| | 19 | 28.07 | 33.32 | 51.41 | 33.45 | 24.30 | 26.95 | 42.83 | 19.90 | 31.95 | 64.68 |
| | 22 | 24.42 | 41.53 | 56.90 | 49.88 | 26.41 | 42.19 | 89.55 | 22.39 | 38.46 | 86.44 |
| | 25 | | 53.48 | 70.27 | 72.59 | 26.65 | 43.35 | 105.31 | 24.46 | 45.84 | 98.51 |
| | 28 | | 70.90 | 81.34 | 97.01 | 33.05 | 70.15 | 162.69 | 34.42 | 50.58 | 119.40 |

In cold storage (Fig.4.21), low temperature resulted in very low values of TSS/acid ratio in all treatments and films. This could be judged from TSS/acid ratio of 41.53, 56.90, 49.88 & 26.41, 42.19, 89.55 and 22.39, 36.51, 86.44 after 22nd day of storage in respective treatments of S-60, LD-60 and LD-80 films respectively. Low values of TSS/acid ratio in all treatments except those at highest level of perforation (N=4) indicated that ripening had not completely taken place in cold stored mangoes. Here treatment with N=4 (perforation area = 1.08×10^{-2} percent) seemed to give reasonable TSS/acid ratio. These results are in agreement with those reported by Thomas (1975), Asraf *et al.* (1981), Saucedo *et al.* (1978), Mukherjee and Srivastava (1979), Singh and Singh (1992), Ulrish (1974), Kalra *et al.* (1988), etc.

4.2.8.1 Statistical Analysis: The statistical results for top three films under different storage environments are presented in Table 4.28. The store means for RT, B&S

Table 4.28 Statistical analysis of TSS/acidity ratio in mangoes

| Duration (days) | Treat. combination means | | | Factor means | | | CD (5%) | | | |
|----------------------|-------------------------------|--------|--------|--------------|--------|-------------------------|------------------|----|-------|-------|
| | T | To | T4-5 | Fl | Tt | St | Tt | Fl | TtXFl | St |
| 10 | 73.05 | 19.94 | 24.25 | 22.82 | 20.66 | 37.80 | 6.10 (27.24). | - | - | 14.93 |
| | | 17.90 | 27.04 | 23.99 | 28.56 | 39.84 | | | | |
| | | 24.13 | 32.62 | 29.99 | 27.34 | 13.22 | | | | |
| 16 | | 36.19 | 71.66 | 59.83 | 42.95 | | 24.37 | - | - | |
| | | 26.16 | 62.65 | 50.49 | 56.54 | | | | | |
| | | 66.51 | 62.69 | 63.96 | 74.80 | | | | | |
| 19 | | 39.10 | 94.73 | 76.19 | 51.53 | | 27.98 | - | - | |
| | | 34.30 | 90.80 | 71.96 | 76.70 | | | | | |
| | | 81.19 | 80.54 | 80.75 | 100.67 | | | | | |
| 22 | | 39.75 | 134.52 | 102.93 | 66.27 | | 30.38 | - | - | |
| | | 52.60 | 101.54 | 85.25 | 105.55 | | | | | |
| | | 106.48 | 125.27 | 119.00 | 135.33 | | | | | |
| NOTE: | Tt: Treatment (To, T4, T5) | | | | | St: Store (RT, B&S, CS) | | | | |
| | Fl: Film (LD-60, LD-80, S-60) | | | | | TtxFl: Interaction | | | | |

and cold storage were 37.80, 39.84 & 13.22 which indicated that both RT and B&S stores had more or less same effect on TSS/acid ratio of the fruits. But TSS/acid ratio in cold storage treatments was significantly lower than non-refrigerated storage which implied that fruits had not been able to reach even desired level of ripening. A mean of 73.05 in control fruits after 10th day indicated how fast the ripening was as compared to film wrapped treatments. The film means did not have much variation during the entire period of storage. The LD-80 films had lowest and optimum film means of 23.99, 50.49, 71.96, 85.22 after 10, 16, 19, 22nd day of storage. A perusal of treatment means showed that different treatments had appreciable difference especially after 16th day and it increased with the duration of storage. This duration is very much important as most of the changes related to ripening in films wrapped fruits took place during this period. The non-perforated treatments had too low values while treatments with highest level of perforations resulted in slightly high TSS/acid ratio. Thus, treatment with 2 perforations (perforation area = 5.4×10^{-3} percent) resulted in somewhat optimum TSS/acid ratio. The CD value (5 percent) of 6.10, 24.37, 27.98, 30.58 for treatments verified the increased effect of treatments on the quality of mangoes. Thus, the statistical results verified the experimental findings.

A summary of above investigations indicated that non-wrapped mangoes could be stored for 7 days with a total loss (PLW + decay + shrinkage) of 20 percent under RT and B&S storage conditions, whereas cold storage could extend it upto 13 days. The LD-80 film was found to be best polymeric film for storing mangoes upto

18-20 days under non-refrigerated storage conditions and 25 days under cold storage conditions.

4.3 SIMULATED TRANSPORTATION STUDIES

These studies were conducted to determine PLW and mechanical damage to the fruits during transportation from field to the market. These two losses computed together gave the transportation loss (TL) and are presented in Table 4.29 and trends of change in Fig.4.22-4.23.

4.3.1 Physiological Loss in Weight (PLW)

It is evident from Table 4.30 that PLW was higher in control than wrapped fruits irrespective of packaging box and duration of transportation. The average PLW was 10.37 and 1.16 percent in control and film wrapped mangoes respectively. Among film wrapped mangoes, LD-80 recorded the least PLW as compared with other two films. Comparing packaging boxes, CFB box recorded least PLW of 3.26 percent while plastic crates contributed slightly higher PLW of 3.72 percent in all the treatments. Higher PLW in plastic crate in comparison with wooden box and CFB box might be due to higher level of air circulation.

4.3.2 Mechanical Damage (MD):

A perusal of Table 4.29 showed that control mangoes had very high mechanical damage (MD) of 24.24 percent compared with 13.25 percent in film wrapped fruits irrespective of film and duration of transportation. Comparing different films, LD-60 recorded slightly higher MD (13.87%) compared with other two films (12.94%). Among packaging boxes, CFB box recorded the least MD of 11.39 percent while wooden box recorded higher MD of 23.18 percent in all the treatments.

Lower MD in CFB box might be due to higher impact resistant cushioning provided by it and prevented physical injury and bruising as caused by nail puncturing in wooden box. Bruising might be due to direct contact of fruits with each other and each layers and direct load of top layers (Joshi and Roy, 1986). Again damage was more pronounced in bottom layers and early softening could have led to development of press marks and deteriorated the quality (Verma and Prakash, 1995).

4.3.3 Transportation Loss (TL):

Transportation loss (TL) increased with the duration of transportation. Now if we take into account non-wrapped fruits in three different packaging boxes (Table 4.29, Fig.4.22), then it is clear that the TL at the end of transportation was 42.57, 30.19, 31.07 percent in wooden box, CFB box and plastic crate respectively. Thus, it is apparent that simply shifting from traditional wooden box to other two packaging options, resulted in reduction of TL from 42.57 percent in wooden box to 30.63 percent (avg.) in other packaging boxes i.e. saving in TL of about 25-30 percent. Comparing wrapped mangoes in different packaging (Fig.4.23) boxes on the other hand, showed a reduction in TL from 21.25 to 10.81 percent (avg) \approx 50 percent saving in TL irrespective of type of the film. Here a combination of CFB box and LD-80 film provided best protection against TL comparing different treatments, the TL in wooden box were 42.57, 21.25 percent (avg.) in non-wrapped and wrapped in LD-60 LD-80 S-60 films respectively. In other two packaging options, the average TL was reduced from 30.19 and 31.07 percent in non-wrapped to 9.48 and 12.48 percent in wrapped fruits in CFB box and plastic crates respectively. Thus, it was concluded

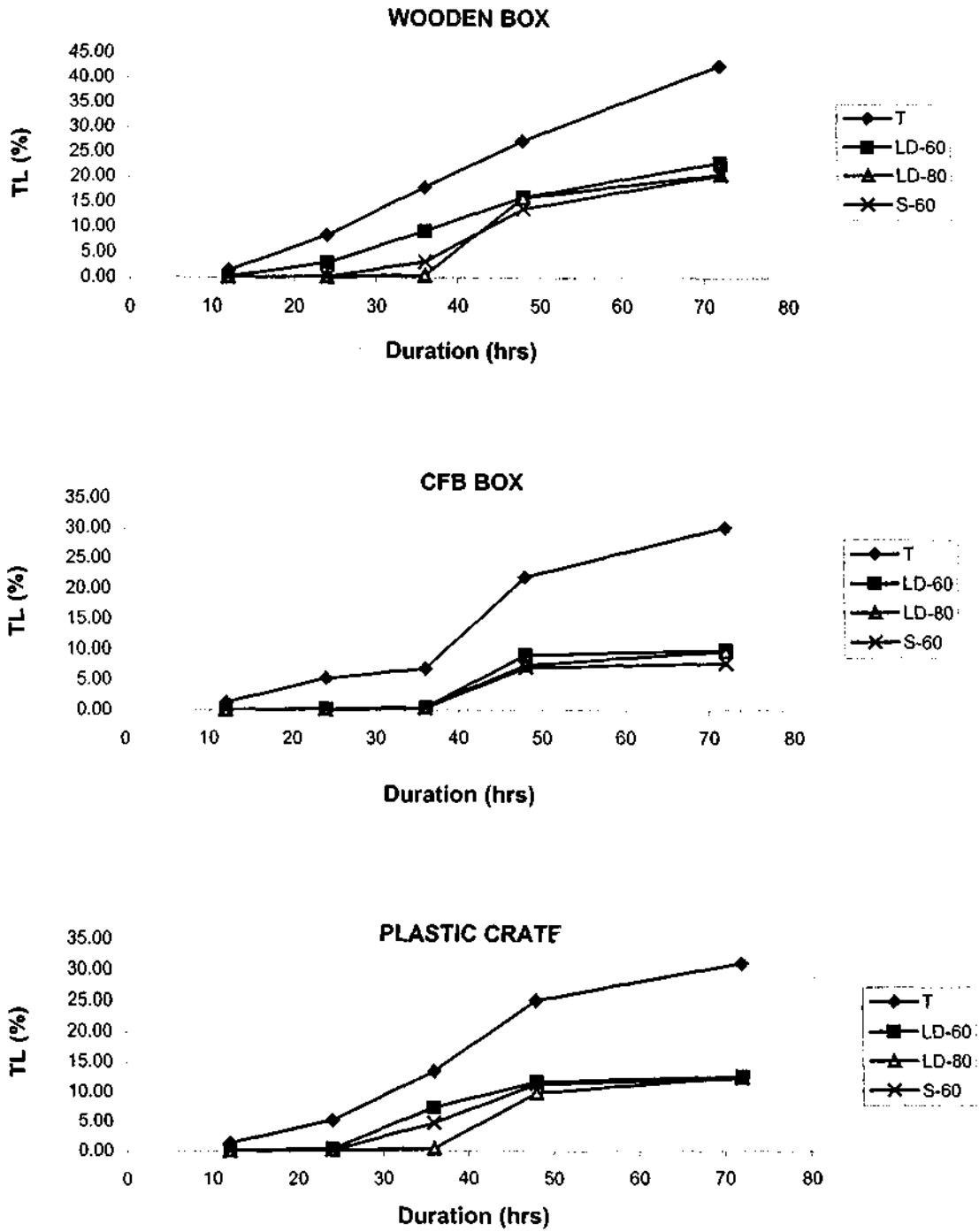
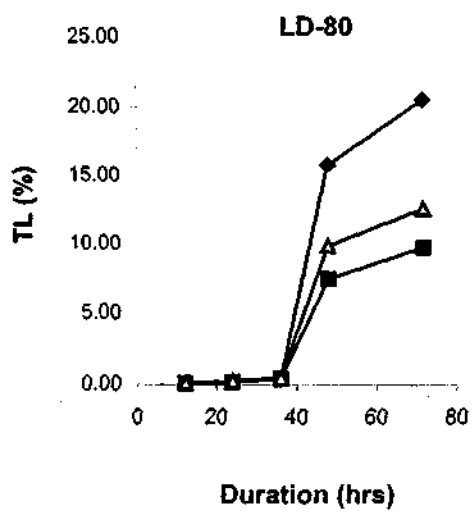
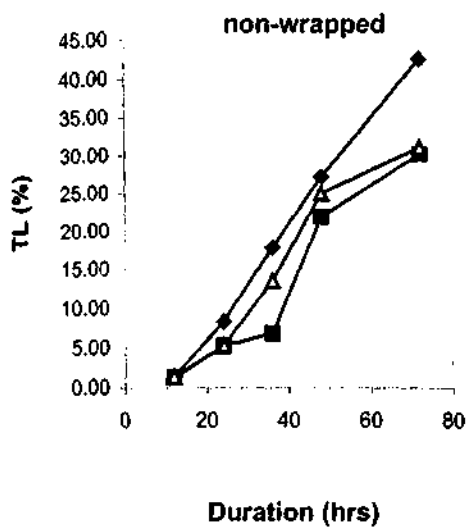
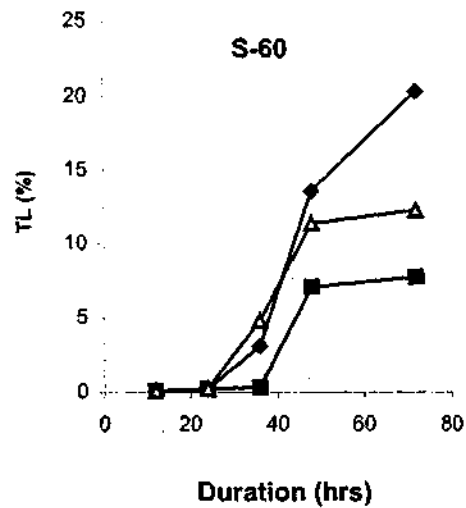
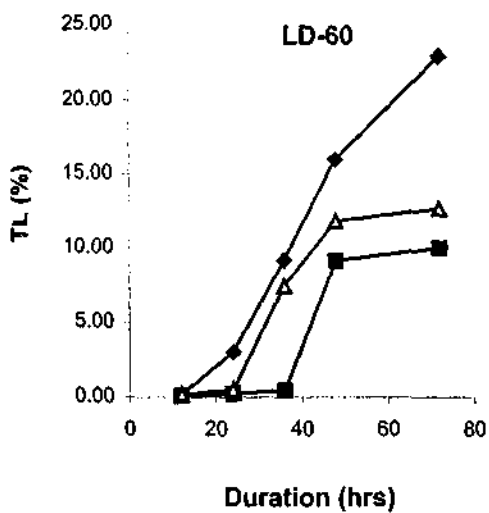


Fig 4.22 Transportation loss in different packages



—◆— WB —■— CFB —▲— PC

—◆— WB —■— CFB —▲— PC



—◆— WB —■— CFB —▲— PC

—◆— WB —■— CFB —▲— PC

Fig 4.23 Transportation loss (TL) in different treatment of mangoes

Table 4.29 Effect of duration of transportation on quality of mangoes

| Duration (hrs) | Different treatments (Control + Films X Packages) | | | | | | | | | | | |
|-------------------|---|-------|-------|-------|-------|-------|------|------|-------|-------|-------|-------|
| | T11 | T12 | T13 | T14 | T15 | T16 | T17 | T18 | T19 | T20 | T21 | T22 |
| | PLW | | | | | | | | | | | |
| 12 | 1.40 | 0.17 | 0.09 | 0.09 | 1.29 | 0.08 | 0.08 | 0.08 | 1.43 | 0.18 | 0.11 | 0.10 |
| 24 | 2.62 | 0.29 | 0.20 | 0.23 | 2.55 | 0.24 | 0.19 | 0.21 | 2.69 | 0.50 | 0.26 | 0.24 |
| 36 | 4.15 | 0.49 | 0.44 | 0.39 | 4.10 | 0.43 | 0.41 | 0.35 | 4.29 | 0.91 | 0.47 | 0.46 |
| 48 | 6.65 | 0.81 | 0.67 | 0.59 | 6.34 | 0.62 | 0.60 | 0.53 | 6.73 | 1.13 | 0.71 | 0.74 |
| 72 | 10.43 | 1.25 | 1.08 | 0.83 | 10.18 | 1.08 | 0.96 | 0.84 | 10.50 | 1.57 | 1.69 | 1.16 |
| | MD | | | | | | | | | | | |
| 12 | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | 5.72 | 2.70 | - | - | 2.77 | - | - | - | 2.63 | - | - | - |
| 36 | 13.71 | 8.65 | - | 2.70 | 2.77 | - | - | - | 9.22 | 6.51 | - | 4.33 |
| 48 | 20.57 | 15.14 | 15.13 | 12.98 | 15.55 | 8.49 | 6.86 | 6.54 | 18.29 | 10.63 | 9.15 | 10.63 |
| 72 | 32.14 | 21.62 | 19.46 | 19.51 | 20.01 | 8.87 | 8.77 | 7.92 | 20.57 | 11.03 | 10.88 | 11.11 |
| | TL (PLW+MD) | | | | | | | | | | | |
| 12 | 1.40 | 0.17 | 0.09 | 0.09 | 1.29 | 0.08 | 0.08 | 0.08 | 1.43 | 0.18 | 0.11 | 0.10 |
| 24 | 8.34 | 2.99 | 0.20 | 0.23 | 5.32 | 0.24 | 0.19 | 0.21 | 5.32 | 0.50 | 0.26 | 0.24 |
| 36 | 17.86 | 9.14 | 0.44 | 3.09 | 6.87 | 0.43 | 0.41 | 0.35 | 13.51 | 7.42 | 0.47 | 4.79 |
| 48 | 27.22 | 15.95 | 15.80 | 13.57 | 21.89 | 9.11 | 7.46 | 7.07 | 25.02 | 11.76 | 9.86 | 11.37 |
| 72 | 42.57 | 22.87 | 20.54 | 20.34 | 30.19 | 9.95 | 9.73 | 8.76 | 31.07 | 12.60 | 12.57 | 12.27 |
| | RIPENING | | | | | | | | | | | |
| 12 | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | - | - | - | - | - | - | - | - | - | - | - | - |
| 36 | 17.14 | - | - | - | - | - | - | - | 8.57 | - | - | - |
| 48 | 25.71 | 2.70 | - | 5.41 | 38.88 | 8.11 | 2.86 | 2.77 | 17.14 | 8.11 | 2.86 | 8.11 |
| 72 | 80.00 | 8.11 | - | 8.11 | 72.22 | 13.51 | 2.86 | 8.33 | 28.58 | 8.11 | 2.86 | 10.81 |

that simply shifting from unwrapping to film wrapping (LD-80/S-60) and then keeping them in either CFB box or plastic crates would result in 70 and 60 percent saving in TL respectively while wooden box would result in 50 percent saving in TL. It is important to mention here that stacking load of upper boxes had not been taken into account. Identical observations were reported by Raghav (2000), Joshi and Roy (1986), Singh and Verma (1995), Verma and Prakash (1995).

4.3.4 Statistical Analysis:

The statistical results showing the effect of time, packaging box and treatments are presented in Table 4.30. As seen from Table 4.30, it is evident that

the effect of interaction of time and treatments were significant. However, effect of interaction of package and treatments was non-significant. The duration means of 2.003, 14.690, 19.371 indicated that effect of time increased with the duration of transportation. The treatment means were 21.90, 9.55, 8.51, 8.12; thereby implying that simply wrapping the fruits would result in considerable reduction of TL. The package means were 15.902, 9.093 and 11.07 which indicated that shifting from

Table 4.30 Effect of polymeric films and packages on transportation loss

| Factor | Description | Means | CD (5%) | | | | | C.V. | | | | | |
|-------------------|---------------|-------|---------|-------|-------|-------|-------|-------|----------------------|--|--|--|--|
| | | | D | T | P | D X T | T X P | | | | | | |
| Duration (hrs) | 24 | 2.00 | 2.187 | 3.295 | 3.520 | 4.374 | - | 28.04 | | | | | |
| | 48 | 14.69 | | | | | | | | | | | |
| | 72 | 19.37 | | | | | | | | | | | |
| Treatments | Control | 21.90 | | | | | | | | | | | |
| | LD-60 | 9.55 | | | | | | | | | | | |
| | LD-80 | 8.51 | | | | | | | | | | | |
| | S-60 | 8.12 | | | | | | | | | | | |
| Packages | Wood. box | 15.90 | | | | | | | | | | | |
| | CFB box | 9.09 | | | | | | | | | | | |
| | Plas. Crate | 11.07 | | | | | | | | | | | |
| NOTE: | D :Duration | | | | | | | | D X T : Interactions | | | | |
| | T :Treatments | | | | | | | | T X P : Interactions | | | | |
| | P :Packages | | | | | | | | | | | | |

traditional practice of wooden box to other two options would result in significant reduction of TL. The CD (5 percent) values for time, treatment and package were 2.187, 2.526/4.065 and 3.52 respectively. Thus, statistical results completely verified our experimental findings.

4.3.5 Colour Development of skin:

The percentage of mangoes in which ripening had started during transportation are shown in Table 4.30. It is clear that rate of ripening (colour change) was quite higher in control fruits compared with film wrapped mangoes especially in wooden box and CFB box during entire period of transportation. The percent ripening in control fruits was 76.11 percent (avg.) in wooden box/CFB box while plastic crate had only 25.58 percent after 72 hours of duration. This might be due to more ventilation in plastic crates; thereby depleting the ethylene environment around the fruit, while other two packages provided a perfectly closed and ethylene enriched environment to facilitate ripening. The film wrapped mangoes, in contrast, had very low ripening. The average amount of mangoes where ripening got started were 9.50 and 1.91 per cent in LD-60/S-60 and LD-80 respectively. Among different packages, CFB box showed higher ripening of 9.06 percent in all films. Whereas other two packaging options had a share of 5.92 percent. Thus, a combination of LD-80 film and plastic crate resulted in lower rate of ripening.

4.4 MATHEMATICAL MODEL

Equations (19), (20) and (21) describe the steady state levels of O_2 , CO_2 and water vapours and equations (22), (23) and (24) describe the dynamics of O_2 , CO_2 and water vapours at any time within the package. All these represent our theoretical results. The model result are discussed as under:

4.4.1 Model Parameters:

Model parameterization was based upon experiments performed with mangoes in a closed system at ambient atmospheric conditions as described in

Chapter 3.1. Several parameters were measured for the system (Table 4.31), some of which were physical parameters of the package viz. weight of fruit, head space free volume, surface area and volume of fruit, etc. Others were physiological characteristics of the fruit studied from independent experiments. Three important parameters are discussed here. The mean transpiration resistance ($\sigma = 1/\rho$) was found to be 0.277 hr/m which was quite low compared to 0.81 hr/m found by Fishman *et al.* (1996) for mangoes. This is because high ambient temperature means high driving force to which fruit skin offered lower resistance against moisture loss. The value of water vapour concentration at saturation (α) was found to be 0.042 which was nearly double to that found for mangoes (0.023) by Fishman *et al.* (1996). The reason to above variation is that water vapour concentration (α) depends upon P_{sat}/T ratio, which increases with the increase in ambient temperature. The values of diffusion coefficient (D) of O₂, CO₂ and water vapours were found to be higher than the one found in studies as stated above. This is because 'D' is directly proportional to $T^{3/2}$, keeping other parameters constant. So increase in temperature resulted in increase in D values for O₂, CO₂ and water vapours.

Table 4.31 Parameters and constants of the system

| Symbols | Description | Value | Dimensions |
|------------------|---|------------------------|---------------------|
| C _A | Gas concentration in ambient atmosphere | | |
| | O ₂ | 21 | percent |
| | CO ₂ | 0.03 | |
| H _A | Relative humidity of ambient atmosphere | 80 | percent |
| H _f | Relative humidity of fruits internal atmosphere | 98 | percent |
| D | Diffusion coefficient in air | | m ² /hr |
| | O ₂ | 0.076 | |
| | CO ₂ | 0.061 | |
| | H ₂ O (Holman, 1990) | 0.095 | |
| P | Permeability coefficient of the film | | m ² /hr |
| | LD-80 | | |
| | O ₂ | 1.057x10 ⁻⁸ | |
| | CO ₂ | 8.791x10 ⁻⁸ | |
| | H ₂ O | 1.187x10 ⁻⁸ | |
| | S-60 | | |
| O ₂ | 4.887x10 ⁻⁹ | | |
| H ₂ O | 1.680x10 ⁻⁸ | | |
| L | Thicknesses of film | | m |
| | LD-80 | 3.094x10 ⁻⁴ | |
| | S-60 | 1.524x10 ⁻⁶ | |
| L _h | Diffusive path length | | m |
| | LD-80 | 5.81x10 ⁻⁴ | |
| | S-60 | 5.65x10 ⁻⁴ | |
| N | Number of pores | 0, 2, 4 | ND* |
| R _h | Radius of pores | 5.5x10 ⁻⁴ | m |
| S | Surface area of the film | 1.851x10 ⁻⁴ | m ² |
| s | Surface area of fruits | 0.0544 | m ² |
| α | Water vapour concentration under saturated atmosphere | 0.042 | ND |
| V | Head space free volume | 3.923x10 ⁻⁶ | m ³ |
| A/W | Area to weight ratio of fruit | 0.812 | cm ² /gm |
| W _o | Initial weight of fruits | 0.670 | Kg |
| ρ | Permeance of fruits surface to water vapour | 3.605 (r=0.277) | m/hr (hr/m) |

* ND – Non-dimensional

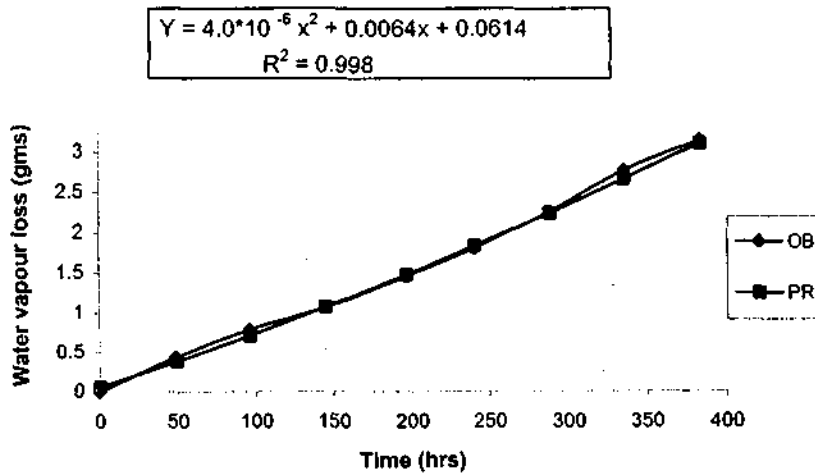
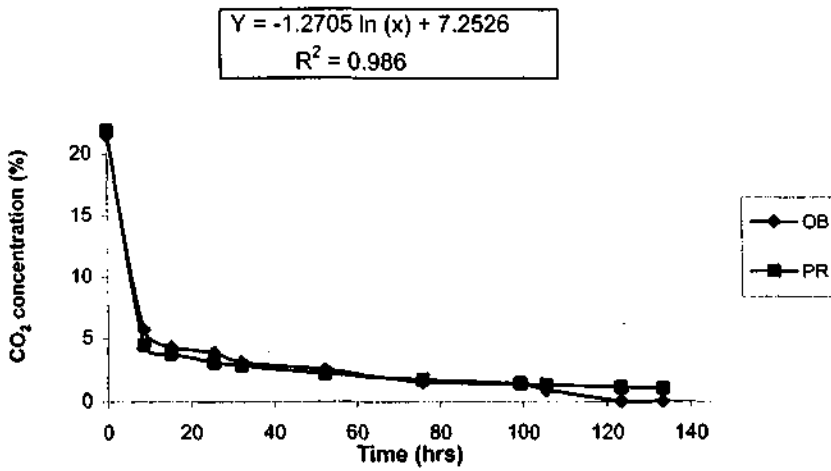
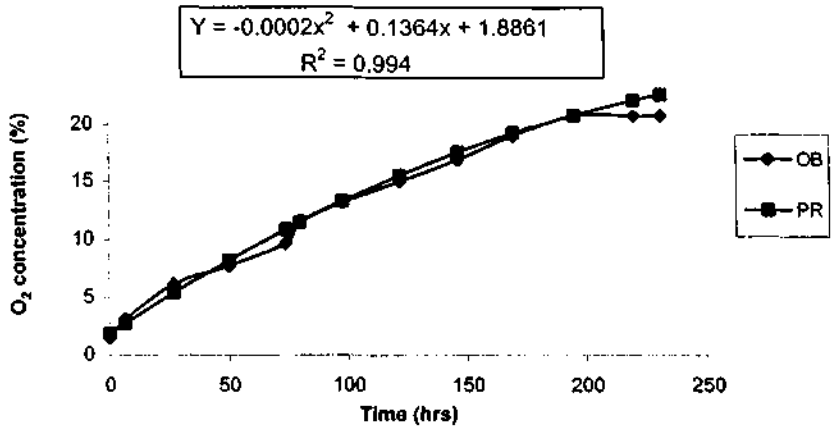
4.4.2 Permeabilities Studies of the Film:

The permeability of LD-80 film to O₂, CO₂ and water vapours were determined experimentally while permeability of S-60 to O₂ and water vapours were available from the published literature (Shetty *et al.*, 1989). The data is presented in Table 4.32 and the trends are shown in Fig.4.24-4.26. The initial levels of O₂, CO₂ concentration were 1.57 and 21.50 per cent. As seen from Fig.4.24-4.25, It is evident that in spite of high gradient of gases available in the beginning, the rise in O₂ level in the chamber was gradual. On the contrary, the CO₂ concentration showed a sharp decline of 73 percent during initial period of 8.5 hours and rest of

Table 4.32 Permeability (O₂,CO₂, water) studies on LD-80 polymeric film

| oxygen | | | | carbondioxide | | | | Water Vapour | | | |
|-----------|--------|--------|-----------|---------------|--------|--------|-----------|--------------|--------|--------|-----------|
| Time(hrs) | Ob (%) | Pr (%) | Deviation | Time(hrs) | Ob (%) | Pr (%) | Deviation | Time(hrs) | Ob (%) | Pr (%) | Deviation |
| 0.00 | 1.57 | 1.89 | -0.32 | 0.00 | 21.5 | 21.88 | -0.38 | 0 | 0.00 | 0.06 | -0.06 |
| 6.68 | 3.15 | 2.79 | 0.36 | 8.55 | 5.77 | 4.53 | 1.24 | 49 | 0.44 | 0.38 | 0.06 |
| 27.21 | 6.18 | 5.45 | 0.73 | 15.13 | 4.34 | 3.80 | 0.54 | 96 | 0.79 | 0.71 | 0.08 |
| 50.38 | 7.79 | 8.25 | -0.46 | 25.52 | 3.89 | 3.14 | 0.75 | 145 | 1.07 | 1.07 | 0.00 |
| 74.08 | 9.71 | 10.89 | -1.18 | 32.07 | 3.13 | 2.85 | 0.28 | 197 | 1.46 | 1.48 | -0.02 |
| 79.89 | 11.50 | 11.51 | -0.01 | 52.25 | 2.52 | 2.23 | 0.29 | 241 | 1.81 | 1.84 | -0.03 |
| 98.08 | 13.21 | 13.34 | -0.13 | 75.82 | 1.58 | 1.75 | -0.17 | 289 | 2.26 | 2.25 | 0.01 |
| 122.12 | 15.06 | 15.56 | -0.50 | 99.48 | 1.34 | 1.41 | -0.07 | 336 | 2.77 | 2.66 | 0.11 |
| 146.40 | 16.94 | 17.57 | -0.63 | 105.60 | 0.95 | 1.33 | -0.38 | 384 | 3.15 | 3.11 | 0.04 |
| 169.92 | 19.03 | 19.29 | -0.26 | 123.50 | 0.03 | 1.13 | -1.10 | | | | |
| 195.40 | 20.84 | 20.90 | -0.06 | 133.50 | 0.03 | 1.03 | -1.00 | | | | |
| 220.16 | 20.84 | 22.22 | -1.38 | | | | | | | | |
| 231.50 | 20.84 | 22.74 | -1.90 | | | | | | | | |

the change took place in 115 hours. The reason to above is that most of the polymeric films commercially available has high permeability to CO₂ and lower to O₂. Kader *et al.* (1989) reported that for most of the available polymeric films; the ratio of CO₂ and O₂ permeabilities are 4 to 6. This limitation largely restricts the use of polymeric films to packaging products that require CO₂ concentration lower than 8



percent (Mannaperuma *et al.*, 1989). Pauly (1989) reported that all polymeric films have a higher permeability to CO₂ than O₂. This is well demonstrated by 220 and 123 hours of time taken by the film to reach steady state levels of O₂ and CO₂ gases, respectively. Moreover, the logarithmic predictive equation for CO₂ also verifies the above fact. The predictive equation for permeability of film to O₂ was polynomial in nature. In contrast to O₂ and CO₂ gases, water vapour flow rate through the film was at a steady rate and flow was more or less constant (Fig.4.26 & Table 4.34). Since the ambient atmosphere in the surrounding continue to change which resulted in zig-zag curves for the above three parameters.

4.4.3 Respiration Rate of Mangoes:

The respiration rate (RR) was determined both in terms of O₂ consumed and CO₂ evolution. The data is presented in Table 4.33. The RR curves are shown in Fig.4.27 and Fig.4.28. The Fig.4.27 showed a steep decline in O₂ levels within the closed door chamber, during initial period of about 3-4 hours; there after it decreased at a much slower rate to reach the steady state. The steep decline in O₂ levels was due to the fact that O₂ uptake by the fruits immediately after harvest increased with time till it reaches its maximum value. This resulted in O₂ vacuum within the chamber. On the other hand, there was no permeation of O₂ from surrounding environment. Thus, respiration rate decreased with the decrease in O₂ levels within the closed chamber. The pattern of change in O₂ level are indicated by logarithmic predictive curve. The respiration rate curve based upon CO₂ evolution showed a gradual increase in CO₂ levels (Fig.4.28) during entire period and pattern of change in CO₂ concentration are shown by polynomial predictive equation. Since

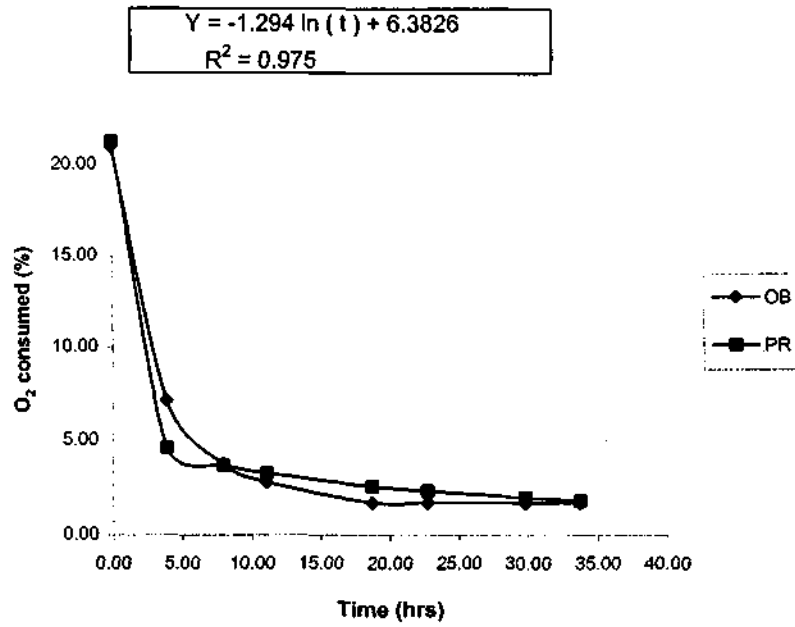


Fig 4.27 Respiration rate curve based on O₂ consumption

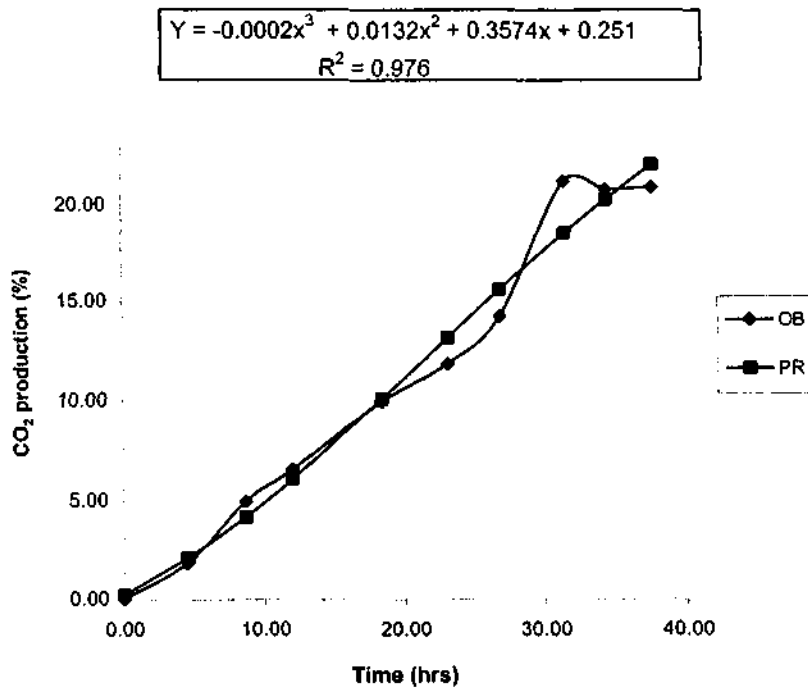


Fig 4.28 Respiration rate curve based on CO₂ production

it took some time for the fruit to discharge CO₂ (metabolism) after O₂ consumption which resulted in more time taken by CO₂ to reach steady state (31.51 hrs) than O₂ gas (22.73 hrs). But if the fruit is kept for more time than the steady state, an aerobic like conditions resulted in sudden increase in the levels of CO₂ which was an indicative of fermentative conditions. Fishman *et al.* (1996) found that O₂ changes exponentially which means steady change while in our case it is logarithmic. This showed the effect of high temperature on respiration rate.

Table 4.33 Respiration rate data based upon O₂ consumption and CO₂ evolution

| Oxygen (%) | | | Carbondioxide (%) | | |
|------------|-------|-------|-------------------|-------|-------|
| Time(hrs) | Ob(%) | Pr(%) | Time(hrs) | Ob(%) | Pr(%) |
| 0.00 | 21.00 | 21.28 | 0.00 | 0.03 | 0.25 |
| 3.90 | 7.14 | 4.62 | 4.53 | 1.86 | 2.12 |
| 7.92 | 3.76 | 3.71 | 8.67 | 5.01 | 4.21 |
| 11.10 | 2.80 | 3.27 | 12.03 | 6.60 | 6.12 |
| 18.77 | 1.73 | 2.59 | 18.46 | 9.97 | 10.12 |
| 22.73 | 1.73 | 2.34 | 23.11 | 11.87 | 13.16 |
| 29.85 | 1.73 | 1.99 | 26.91 | 14.25 | 15.64 |
| 33.75 | 1.73 | 1.83 | 31.51 | 21.23 | 18.55 |
| | | | 34.46 | 20.84 | 20.31 |
| | | | 37.73 | 20.94 | 22.11 |

4.4.4 Model Validation:

To validate the model, its predictions were compared with experiments on mango fruit in a simulated MA package with perforated (N=2,4) and non-perforated films (N=0). For all computations independently estimated parameters were used (Table 4.31).

4.4.4.1 Oxygen: The predicted and experimental values of O₂ concentration in LD-80 film are presented in Table 4.34 and trends are shown in Fig.4.29-4.31. The

predicted steady state O_2 concentration from equation (19) yield $C^* = 2.52$ for non-perforated film ($N=0$, $S_h=0$) and $C^* = 6.95$, ($N=2$), $C^* = 7.75$ ($N=4$) per cent in perforated treatments of LD-80 film respectively. The experimental values (Table 4.34) at corresponding treatments were 2.66, 6.79, 7.59 which showed an average variation of 0.14 and 0.16 percent with predicted values in non-perforated and perforated treatments respectively. Slightly more variation in perforated treatments was due to more exposure to outside environment. It was also clear that simply perforating the film resulted in increase in the O_2 concentration and rate of this increase in O_2 concentration decreased with the increase in N . This is well demonstrated by the fact that at $N=2$, O_2 concentration increased by 255 percent of what is there in non-perforated film ($N=0$), however, doubling the perforations ($N=4$), resulted in further only 30 percent increase in O_2 level. Similar trends were found in S-60 film (Table 4.34 and Fig.4.32-4.34). The predicted and experimental steady state values were 2.44, 6.98, 7.78 per cent and 2.35, 6.60, 7.54 per cent in respective treatments ($N=0, 2, 4$). This showed an average variation of 0.09 and 0.31 per cent in non-perforated and perforated treatments of predicted and experimental values. Again the difference between predicted values of non-perforated treatments in LD-80 and S-60 films was lower than among perforated treatments. The predicted value of O_2 concentration in non-perforated treatments of LD-80 was higher than corresponding treatment in S-60 film. This might be due to high O_2 permeability coefficient of LD-80 than S-60 film. However, the O_2 concentration in perforated treatments was in the reverse order. This is because, in perforated treatments, the flow through perforation accounts for nearly 97-98 percent

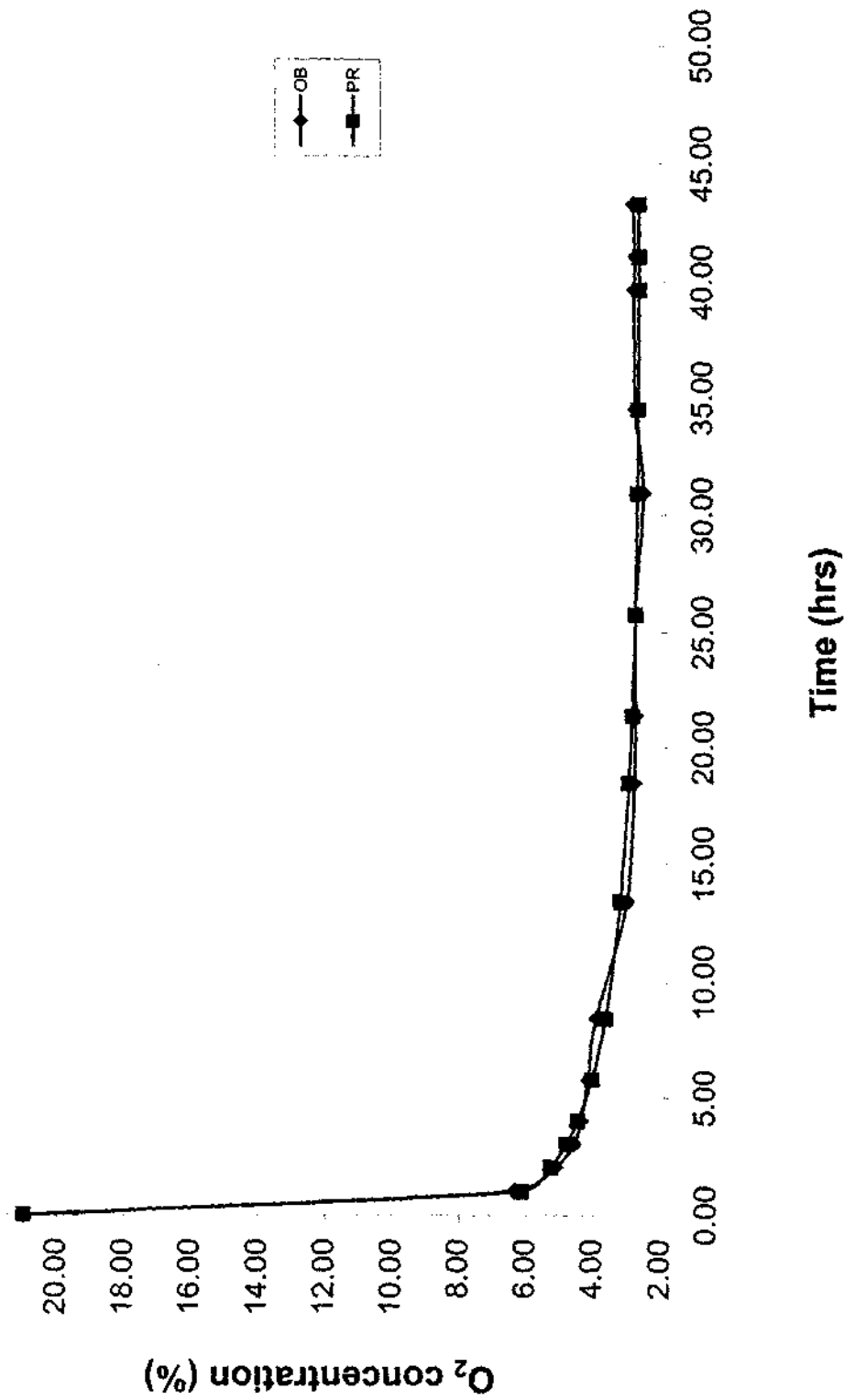


Fig 4.29 Observed and predicted O₂ conc. in LD-80 film package at N=0

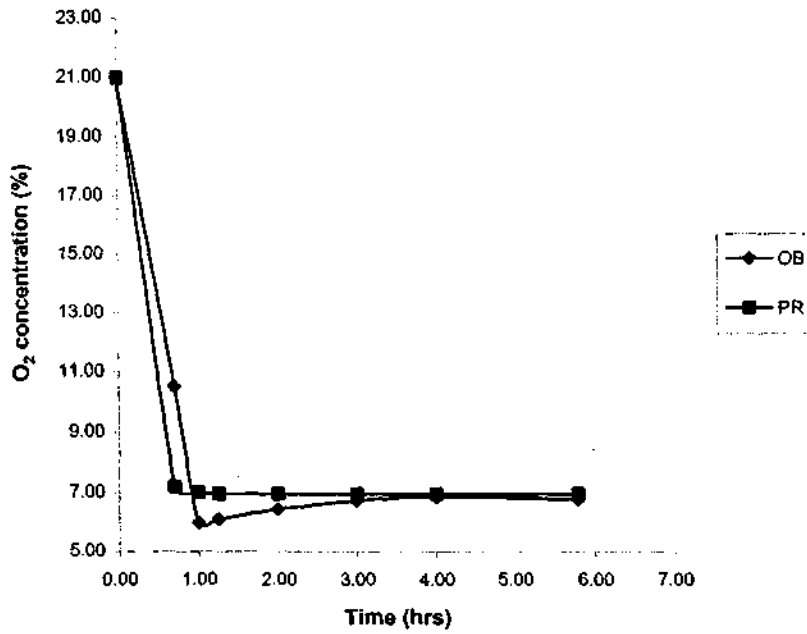


Fig 4.30 Observed and predicted O₂ conc. in LD-80 film package at N=2

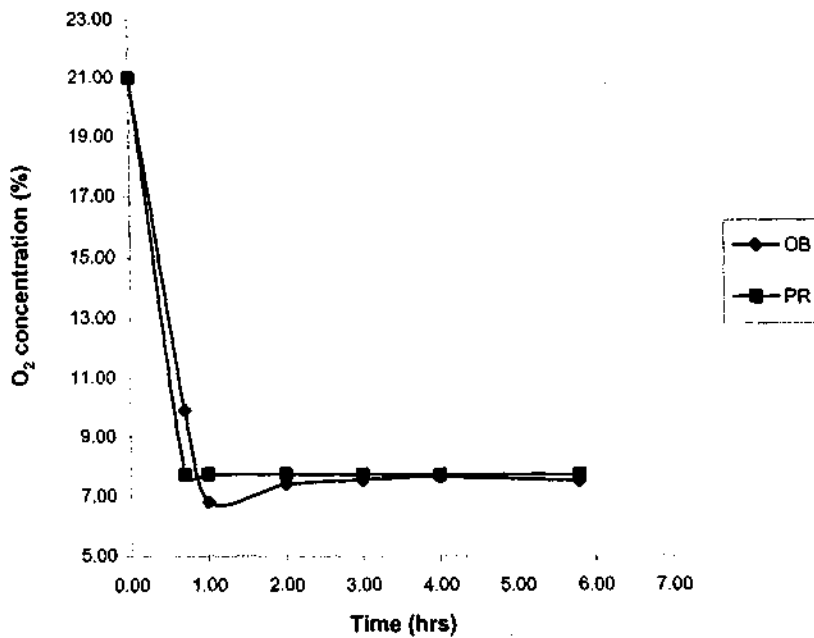


Fig 4.31 Observed and predicted O₂ conc. in LD-80 film package at N=4

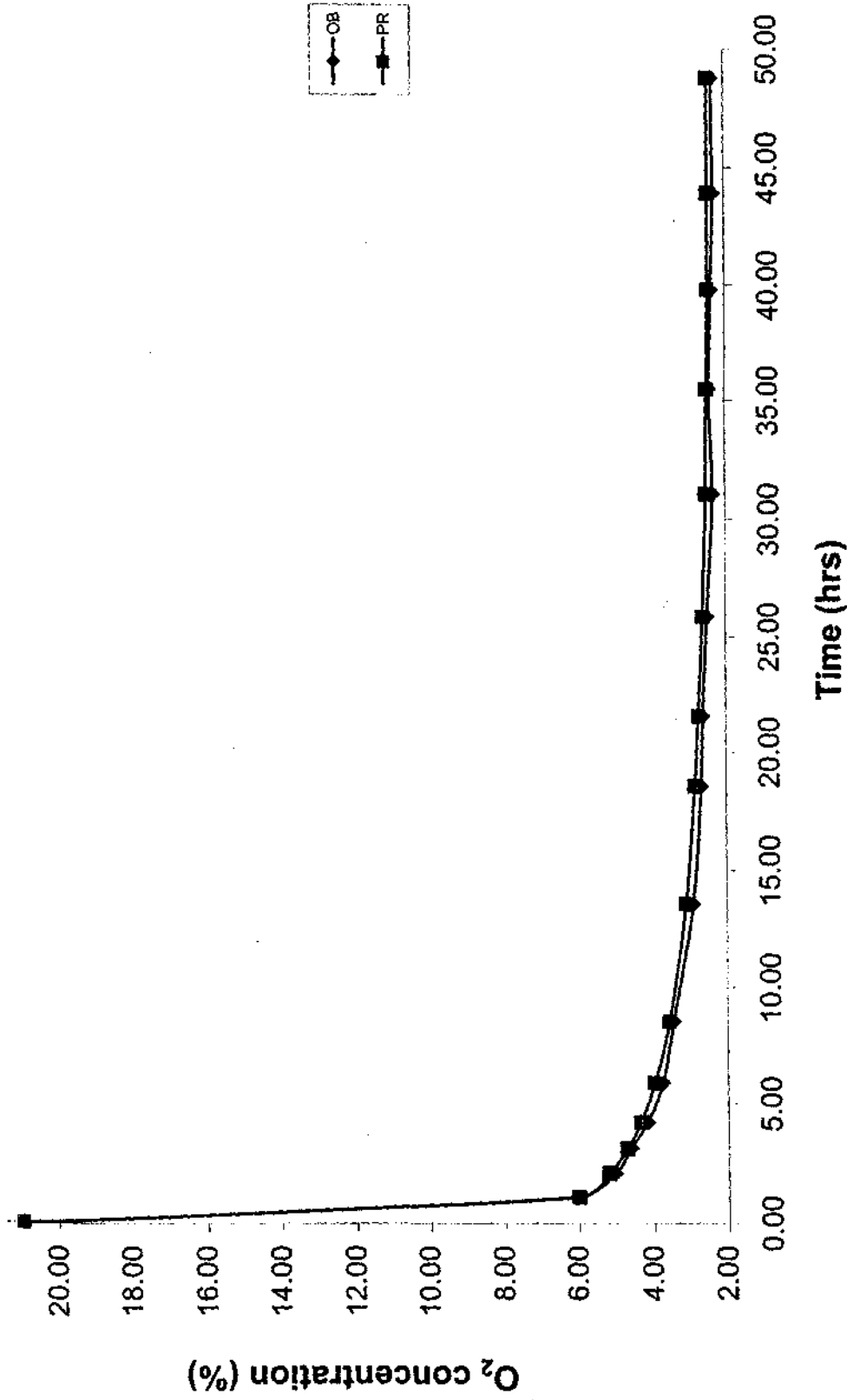


Fig 4.32 Observed and predicted O₂ conc. in S-60 film package at N=0

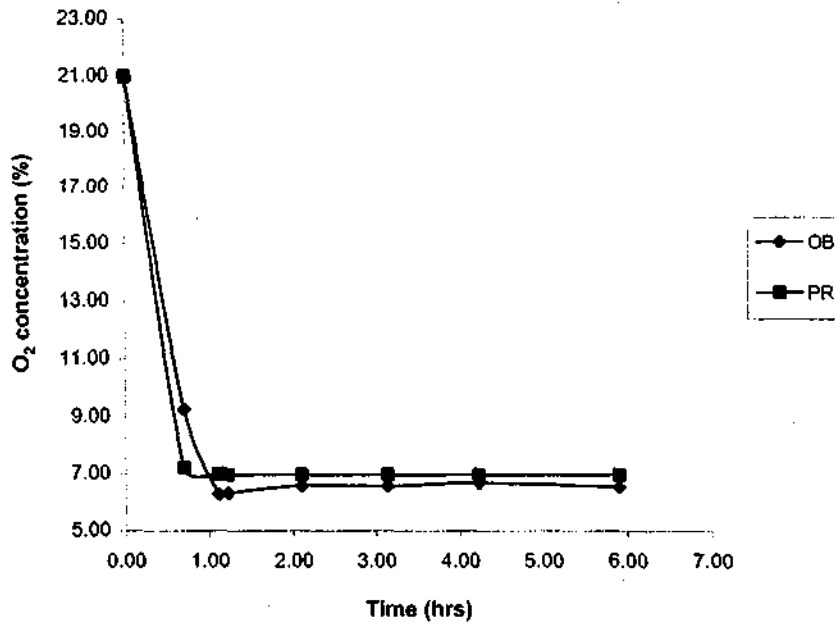


Fig 4.33 Observed and predicted O₂ conc. in S-60 film package at N=2

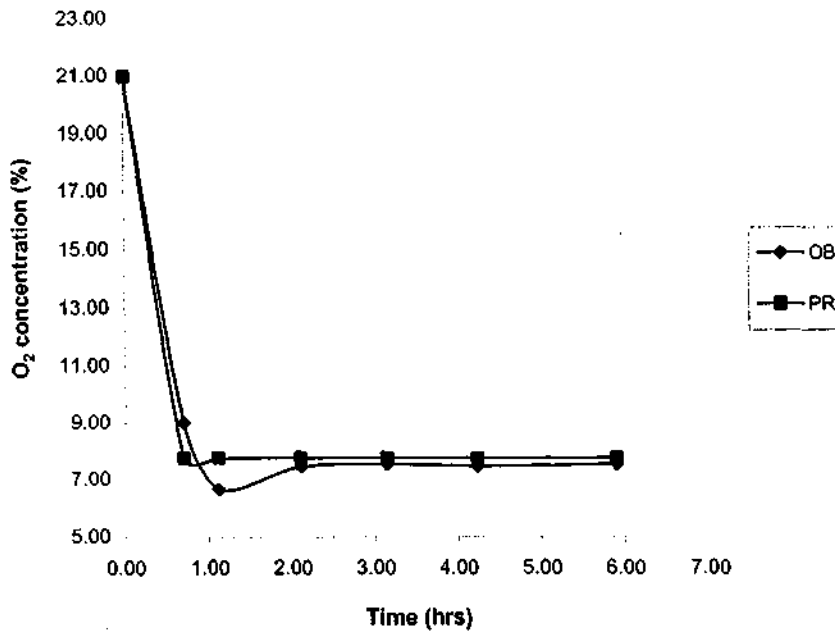


Fig 4.34 Observed and predicted O₂ conc. in S-60 film package at N=4

Table 4.34 Observed and predicted values of O₂ as effected by number of perforations (N) in LD-80 and S-60 films

| N=0 | | | N=2 | | | N=4 | | |
|--------------|--------|--------|------------|--------|--------|------------|--------|--------|
| Time (hrs) | Ob (%) | Pr (%) | Time (hrs) | Ob (%) | Pr (%) | Time (hrs) | Ob (%) | Pr (%) |
| LD-80 | | | | | | | | |
| 0.00 | 21.00 | 21.00 | 0.00 | 21.00 | 21.00 | 0.00 | 21.00 | 21.00 |
| 1.00 | 6.35 | 6.13 | 0.70 | 10.51 | 7.19 | 0.70 | 9.93 | 7.75 |
| 2.00 | 5.11 | 5.26 | 1.00 | 5.99 | 7.01 | 1.00 | 6.81 | 7.75 |
| 3.00 | 4.53 | 4.76 | 1.25 | 6.10 | 6.95 | 2.00 | 7.41 | 7.75 |
| 4.00 | 4.32 | 4.42 | 2.00 | 6.44 | 6.95 | 3.00 | 7.57 | 7.75 |
| 5.79 | 4.11 | 3.99 | 3.00 | 6.73 | 6.95 | 4.00 | 7.67 | 7.75 |
| 8.44 | 3.86 | 3.58 | 4.00 | 6.87 | 6.95 | 5.79 | 7.53 | 7.75 |
| 13.39 | 2.94 | 3.13 | 5.79 | 6.78 | 6.95 | | | |
| 18.45 | 2.71 | 2.87 | | | | | | |
| 21.33 | 2.68 | 2.77 | | | | | | |
| 25.76 | 2.67 | 2.66 | | | | | | |
| 30.89 | 2.41 | 2.58 | | | | | | |
| 34.50 | 2.64 | 2.55 | | | | | | |
| 39.63 | 2.67 | 2.52 | | | | | | |
| 41.05 | 2.63 | 2.52 | | | | | | |
| 43.26 | 2.64 | 2.52 | | | | | | |
| S-60 | | | | | | | | |
| 0.00 | 21.00 | 21.00 | 0.00 | 21.00 | 21.00 | 0.00 | 21.00 | 21.00 |
| 1.11 | 6.07 | 5.99 | 0.70 | 9.27 | 7.21 | 0.70 | 9.03 | 7.78 |
| 2.10 | 5.03 | 5.19 | 1.11 | 6.30 | 7.01 | 1.11 | 6.68 | 7.78 |
| 3.14 | 4.61 | 4.70 | 1.22 | 6.33 | 6.98 | 2.10 | 7.46 | 7.78 |
| 4.23 | 4.16 | 4.34 | 2.10 | 6.50 | 6.98 | 3.14 | 7.56 | 7.78 |
| 5.90 | 3.74 | 3.96 | 3.14 | 6.58 | 6.98 | 4.23 | 7.49 | 7.78 |
| 8.55 | 3.44 | 3.55 | 4.23 | 6.69 | 6.98 | 5.90 | 7.56 | 7.78 |
| 13.58 | 2.89 | 3.09 | 5.90 | 6.55 | 6.98 | | | |
| 18.56 | 2.66 | 2.83 | | | | | | |
| 21.52 | 2.61 | 2.73 | | | | | | |
| 25.88 | 2.49 | 2.61 | | | | | | |
| 31.04 | 2.33 | 2.52 | | | | | | |
| 35.48 | 2.41 | 2.48 | | | | | | |
| 39.81 | 2.37 | 2.45 | | | | | | |
| 43.93 | 2.29 | 2.44 | | | | | | |
| 48.77 | 2.33 | 2.44 | | | | | | |

while flow through film is only 2-3 per cent and diffusive path length was lower in S-60 film than LD-80 film i.e. more distance to cover for gas flow in LD-80 film and hence, lower O₂ concentration in perforated treatments. Thus, in non-perforated treatments it is the type of film which is more important, but in perforated treatments, the thicknesses of the film and area of perforations which is more important.

4.4.4.2 Carbondioxide: The predicted and experimental values of CO₂ concentration in LD-80 film are presented in Table 4.35 and trends are shown in Fig.4.35. In LD-80 film, the predicted steady state CO₂ con from equation (20) yield C* = 15.53, 6.38, 4.08 per cent at N = 0, 2, 4 respectively. The experimental values (Table 4.35) at corresponding treatments were around 15.61, 6.60, 4.20 per cent

Table 4.35 Observed and predicted values of CO₂ as effected by number of perforations(N) in LD-80 film

| N=0 | | | N=2 | | | N=4 | | |
|------------|--------|--------|------------|--------|--------|------------|--------|--------|
| Time (hrs) | Ob (%) | Pr (%) | Time (hrs) | Ob (%) | Pr (%) | Time (hrs) | Ob (%) | Pr (%) |
| 0.00 | 0.03 | 0.03 | 0.00 | 0.03 | 0.03 | 0.00 | 0.03 | 0.03 |
| 5.79 | 2.34 | 2.32 | 5.79 | 2.01 | 1.83 | 5.79 | 1.33 | 1.52 |
| 8.44 | 3.26 | 3.48 | 8.44 | 2.54 | 2.52 | 8.44 | 2.18 | 1.98 |
| 13.39 | 5.32 | 5.69 | 13.39 | 3.27 | 3.62 | 13.39 | 2.54 | 2.66 |
| 18.45 | 8.04 | 7.91 | 18.45 | 4.50 | 4.54 | 18.45 | 3.00 | 3.19 |
| 25.76 | 10.30 | 10.84 | 25.76 | 5.08 | 5.52 | 25.76 | 3.42 | 3.71 |
| 30.89 | 12.18 | 12.58 | 30.89 | 5.66 | 5.99 | 30.89 | 4.01 | 3.94 |
| 34.50 | 13.71 | 13.59 | 34.50 | 6.26 | 6.21 | 34.50 | 4.20 | 4.03 |
| 39.63 | 14.80 | 14.69 | 39.63 | 6.59 | 6.38 | 39.63 | 4.18 | 4.08 |
| 43.46 | 15.67 | 15.23 | 43.46 | 6.54 | 6.38 | 43.46 | 4.15 | 4.08 |
| 48.63 | 15.39 | 15.53 | 48.63 | 6.59 | 6.38 | 48.63 | 4.27 | 4.08 |
| 52.10 | 15.53 | 15.53 | 52.10 | 6.66 | 6.38 | 52.10 | 4.18 | 4.08 |
| 56.23 | 15.55 | 15.53 | | | | | | |

respectively which showed an average variation of 0.08 and 0.17 per cent in non-perforated and perforated treatments respectively. The more variation in perforated treatments is due to more exposure to surrounding ambient environment i.e. more

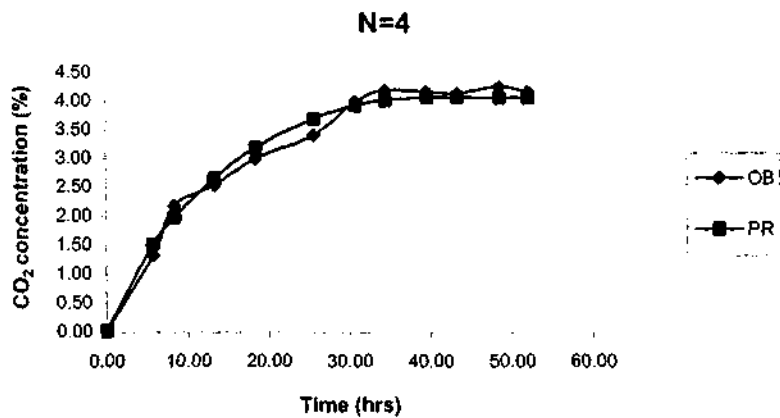
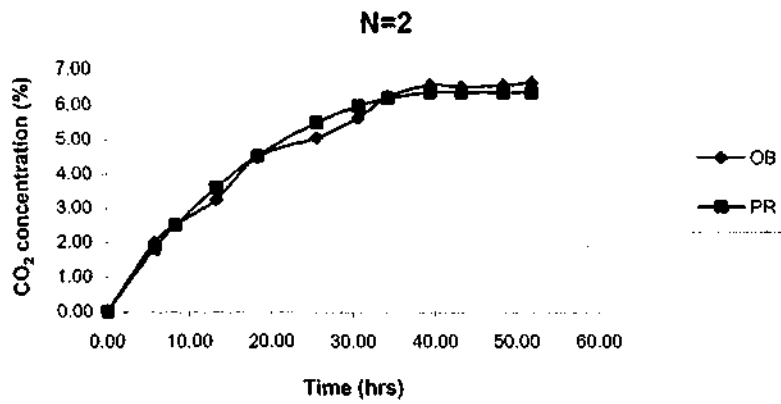
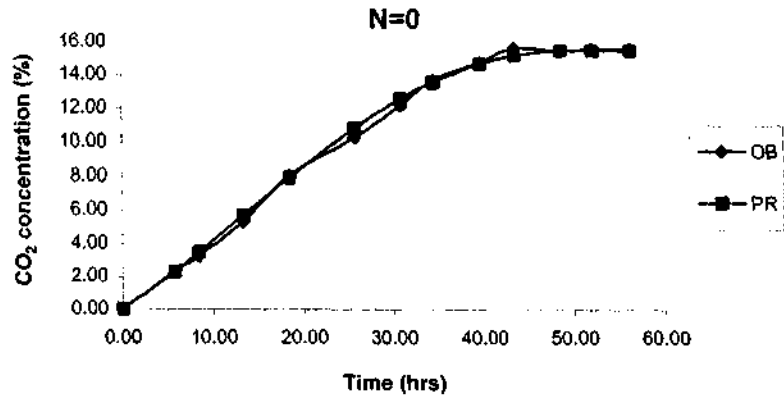


Fig 4.35 Observed and predicted CO₂ conc. in LD-80 film

sensitivity in case of perforated treatments. So any change in outside environment caused immediate variation in the package environment. Perforation simply reduces the excessive CO₂ concentration within the package and this effect decreases with the increase in perforation level (i.e. N increase). This is well demonstrated by the fact that at N=2, CO₂ concentration is reduced to 58 percent of what is there in non-perforated film (N=0), however doubling the perforation (N=4), result in further 15 per cent decrease in the levels of CO₂ concentration

4.4.4.3 Steady state times for Gases: The steady state times for O₂ and CO₂ are presented in Table 4.38. As seen from Table 4.38, it is clear that the predicted times for reaching steady state levels of O₂ in perforated film (N=2) were negligible (1.25, 0.70 hr) compared with 38.41 hours in non-perforated treatments. As explained earlier that perforation simply resulted in higher level of O₂ concentration but this effect was more pronounced on time to reach the steady state. Similar trends were found in S-60 film as indicated by time values of 41.6, 1.22, 0.69 hours in respected treatments. So difference in time values between both the films was more in non-perforated treatments. This is because here film permeability play more important role which depends upon type of film and in most commercial films resistance of film to O₂ flow is very high resulting in more time to reach steady state. But in perforated treatments, number of perforations (% area) played more important role and more exposure to outside environment reduces the reaction time. The steady state time for CO₂ gas in LD-80 film were 48.50, 39.47, 37.73 hours in respective treatments (N=0,2,4). Thus perforation did effect the steady state time but difference in steady state times between non-perforated and perforated treatments was not very

significant. Thus, perforation resulted in wide variation in steady state times between both gases. This is because oxygen diffuses \approx 30 percent faster than CO₂ in air, which implies that the permeability of a perforation to O₂ is 1.3 times higher than its permeability to CO₂ (Nobel, 1991).

4.4.4.4 Relative Humidity: The predicted and experimental values of RH are presented in Table 4.36 and trends of change are shown in Fig.4.36. The predicted steady state RH values were 100, 99.97, 99.94 per cent in respective treatments in both the films. The experimental values (Table 4.36) were 99 per cent in all treatments of both the films. The dynamics of RH showed that practically there was no difference between perforated and non-perforated packages and between experimental and predicted values. The visible lag in experimental approach to steady state RH as compared with model predictions, was related to time required to reach equilibrium between in-package environment and near sensor environment of the equipment i.e. sensitivity of equipment or probe reaction time is very important,

Table 4.36 Observed and predicted values of water vapour concentration(RH) as effected by number of perforations (N) in LD-80 films

| N=0 | | | N=2 | | | N=4 | | |
|------------|--------|--------|------------|--------|--------|------------|--------|--------|
| Time (hrs) | Ob (%) | Pr (%) | Time (hrs) | Ob (%) | Pr (%) | Time (hrs) | Ob (%) | Pr (%) |
| 0.00 | 80.00 | 80.00 | 0.00 | 80.00 | 80.00 | 0.00 | 80.00 | 80.00 |
| 0.02 | 83.80 | 100.00 | 0.02 | 83.80 | 99.97 | 0.02 | 83.80 | 99.94 |
| 1.00 | 99.00 | 100.00 | 1.00 | 99.00 | 99.97 | 1.00 | 99.00 | 99.94 |
| 2.00 | 99.00 | 100.00 | 2.00 | 99.00 | 99.97 | 2.00 | 99.00 | 99.94 |
| 3.00 | 99.00 | 100.00 | 3.00 | 99.00 | 99.97 | 3.00 | 99.00 | 99.94 |
| 4.00 | 99.00 | 100.00 | 4.00 | 99.00 | 99.97 | 4.00 | 99.00 | 99.94 |
| 6.00 | 99.00 | 100.00 | 6.00 | 99.00 | 99.97 | 6.00 | 99.00 | 99.94 |
| 8.00 | 99.00 | 100.00 | 8.00 | 99.00 | 99.97 | 8.00 | 99.00 | 99.94 |
| 13.00 | 99.00 | 100.00 | 13.00 | 99.00 | 99.97 | 13.00 | 99.00 | 99.94 |

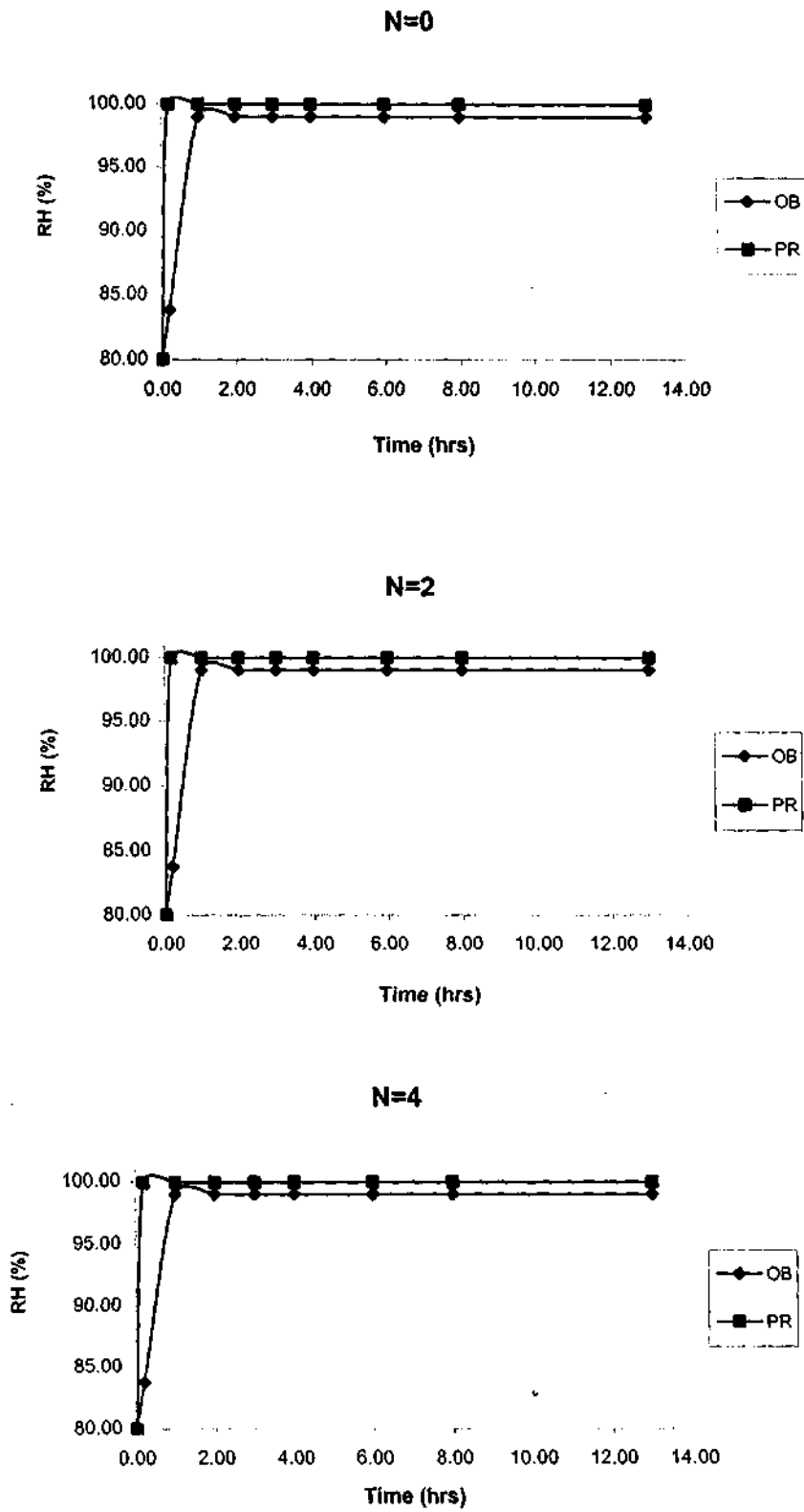


Fig 4.36 Observed and predicted RH in LD-80 film

which can be in hours or minutes and is greatly effected when it is used at RH close to 100 per cent. Moreover, insignificant difference in RH values of different treatments indicated that type and thicknesses of the film and number of perforations (under above stated condition) did not have any effect on RH in the package environment. The characteristics times were 0.02001, 0.01998, 0.01994 hours thereby indicating that 63 per cent level of steady state is reached within 12 minutes irrespective of the treatments. The characteristics times were much shorter than those of the climacteric changes which were observed in our experiment within one hour after beginning of experiment. This justified our assumptions of constant parameters.

Result showed that perforation affected the dynamics and steady state concentration of gases (O_2/CO_2) in MAP much more stronger than those of water vapours. The concentration of gases in perforated and non-perforated packages differ by an order of magnitude while in package RH levels were practically equal. These quantitative results depends upon specific parameters of the system like weight of fruit, in-package and ambient RH, head space free volume, area and thickness of the film. So, results would be different with different parameters as predicted from the model. The contribution of perforation to the creation of MA inside the package could be estimated from model by comparison between flow through film and holes, both for gases and RH or more simply from P and D values. The relation between O_2 flow through perforated and non-perforated film was 41.79, 82.58 at N=2 and 4 respectively whereas similar ratio for CO_2 was 4.77, 8.55 at

respective levels. This explains that perforation has much more pronounced effect on O₂ than CO₂. Similar results were found for S-60 films.

4.4.5 Model Predictions:

Changing the number of perforations per package means changing the water vapour transmission rate of the film. Alteration of RH in the ambient atmosphere would then change the driving force for water vapour permeation through the film. The steady state RH changes within the package predicted by the model equation (21) for films with seven levels of perforations (N=0,2,4,10,20,30,40) and three levels of ambient atmosphere RH levels (80,70,60 percent) are presented in Table 4.37 and trends are shown in Fig.4.37 for LD-80 film and Fig.4.38 for S-60 film. The transient period of these combination of parameters were very short and varied slightly (Table 4.37). As expected lowering of ambient RH reduced the predicted in package RH, because of increased RH gradient across the packaging film. Increasing the number of perforations (N), makes the in-package RH more sensitive

Table 4.37 Model predictions of characteristic times and water vapour concentrations (RH) as affected by number of perforations (N) in LD-80 and S-60 films

| No. of perforations (N) | LD-80 | | | | S-60 | | | |
|-------------------------|-------------------|--------|--------|--------|-------------------|--------|--------|--------|
| | Chac.Time t*(hrs) | RH (%) | | | Chac.Time t*(hrs) | RH (%) | | |
| | | 80 | 70 | 60 | | 80 | 70 | 60 |
| 0 | 0.02001 | 100.00 | 100.00 | 100.00 | 0.02001 | 100.00 | 100.00 | 100.00 |
| 2 | 0.01998 | 99.97 | 99.95 | 99.94 | 0.01997 | 99.97 | 99.95 | 99.93 |
| 4 | 0.01994 | 99.94 | 99.90 | 99.87 | 0.01994 | 99.93 | 99.90 | 99.87 |
| 10 | 0.01985 | 99.84 | 99.76 | 99.68 | 0.01984 | 99.84 | 99.76 | 99.67 |
| 20 | 0.01970 | 99.69 | 99.53 | 99.38 | 0.01969 | 99.68 | 99.52 | 99.36 |
| 30 | 0.01954 | 99.54 | 99.30 | 99.07 | 0.01953 | 99.52 | 99.28 | 99.04 |
| 40 | 0.01939 | 99.39 | 99.08 | 98.77 | 0.01938 | 99.37 | 99.05 | 98.74 |

to the ambient RH and accordingly steady state RH decreased with the increase in perforations and decrease in ambient RH. But in no case the RH decreased below

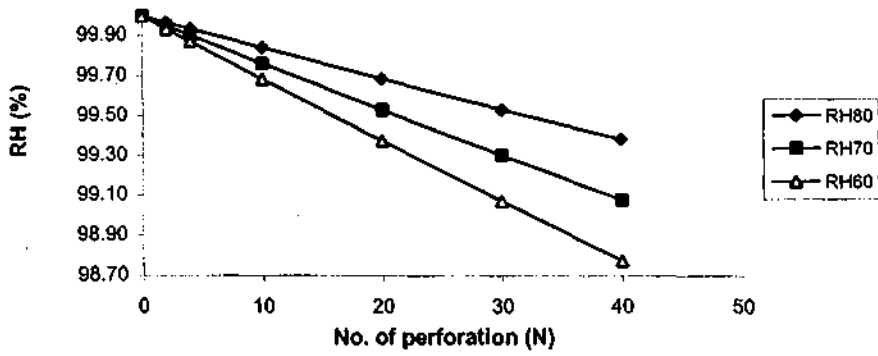


Fig 4.37 Predicted RH in LD-80 film package at different perforations & outside RH

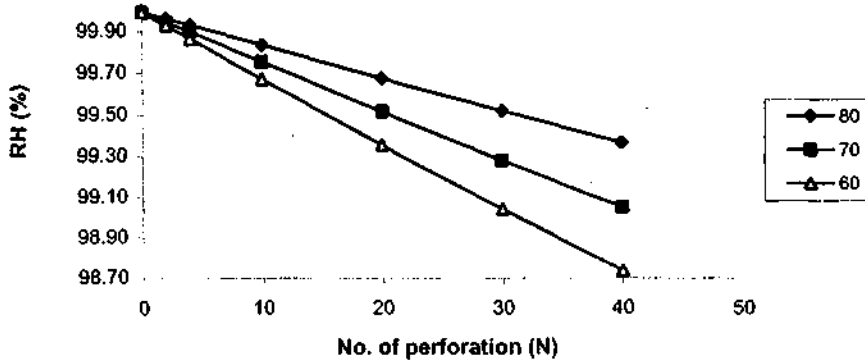


Fig 4.38 Predicted RH in S-60 film package at different perforations & outside RH

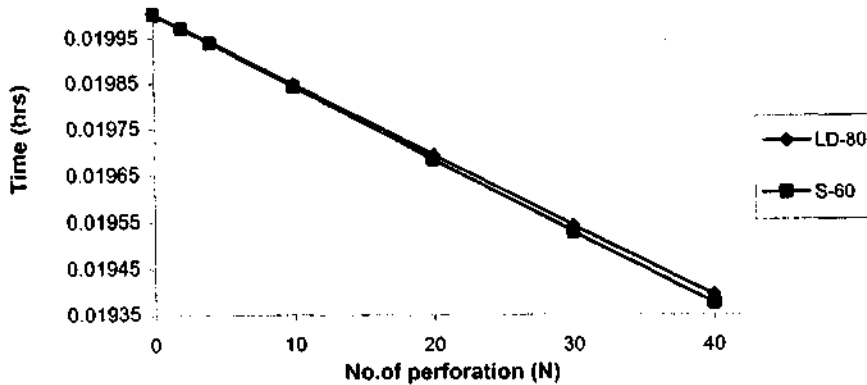


Fig 4.39 Characteristic time as effected by no. of perforations in different films

98 per cent at highest level of perforations (N=40) and lowest level of ambient RH (60 percent). Our preliminary measurements confirmed the model predictions. The increase in number of perforations and decrease in RH of outside ambient environment did not have much effect on the characteristic times which remained around 12 minutes as shown in Table 4.37 and Fig.4.39.

The steady state O₂ concentration for 6 levels of perforations (N=0,1,2,4,10,20) are presented in Table 4.38 and shown in Fig.4.40 which showed that simply making perforations resulted in more transmission of O₂ than non-perforated film. However, the effect of perforations reduced substantially with more increase in number of perforations. This has been well demonstrated by steady state levels of O₂ concentration at different N (Table 4.38/Fig.4.40). Similar trends were observed in steady state CO₂ concentration with the change in perforation levels (Fig.4.40/Table 4.38). One important findings of the study was that at N=1 (perforation area $\approx 2.7 \times 10^{-3}$ percent), the O₂ and CO₂ concentration that can be achieved are 6.15 and 9.00 respectively which are very close to the required levels

Table 4.38 Predicted values of steady state times and steady state gas concentration in LD-80 film

| No. of perforations (N) | Steady state time (hrs) | | | Steady state gas conc. (%) | | |
|-------------------------|-------------------------|-------|-----------------|----------------------------|------|-----------------|
| | O ₂ | | CO ₂ | O ₂ | | CO ₂ |
| | LD-80 | S-60 | LD-80 | LD-80 | S-60 | LD-80 |
| 0 | 38.41 | 41.60 | 48.50 | 2.52 | 2.44 | 15.53 |
| 1 | 2.41 | 2.31 | 43.21 | 6.15 | 6.18 | 9.00 |
| 2 | 1.25 | 1.22 | 39.47 | 6.95 | 6.98 | 6.38 |
| 4 | 0.70 | 0.69 | 37.73 | 7.75 | 7.78 | 4.08 |
| 10 | 0.30 | 0.30 | 34.27 | 8.82 | 8.85 | 1.98 |
| 20 | 0.17 | 0.17 | 32.29 | 9.62 | 9.65 | 1.08 |

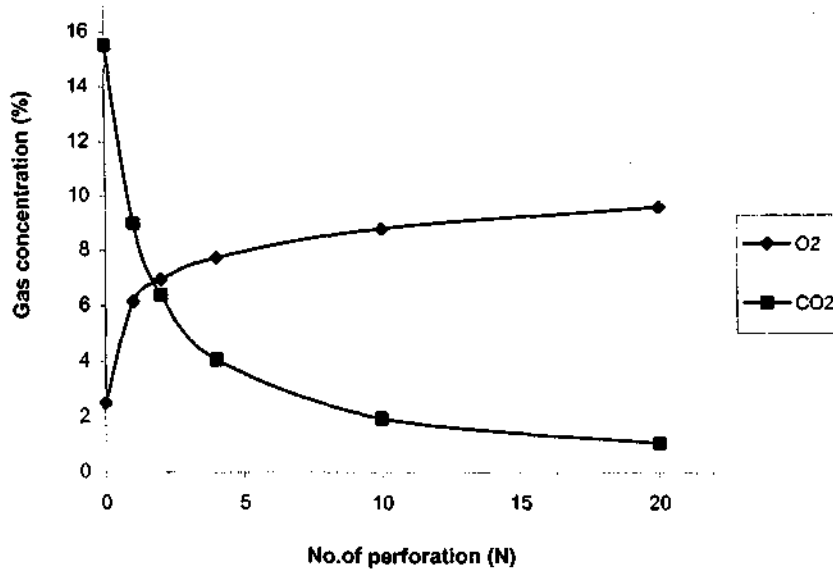


Fig 4.40 Predicted steady state concentrations of O₂ and CO₂ in LD-80 film

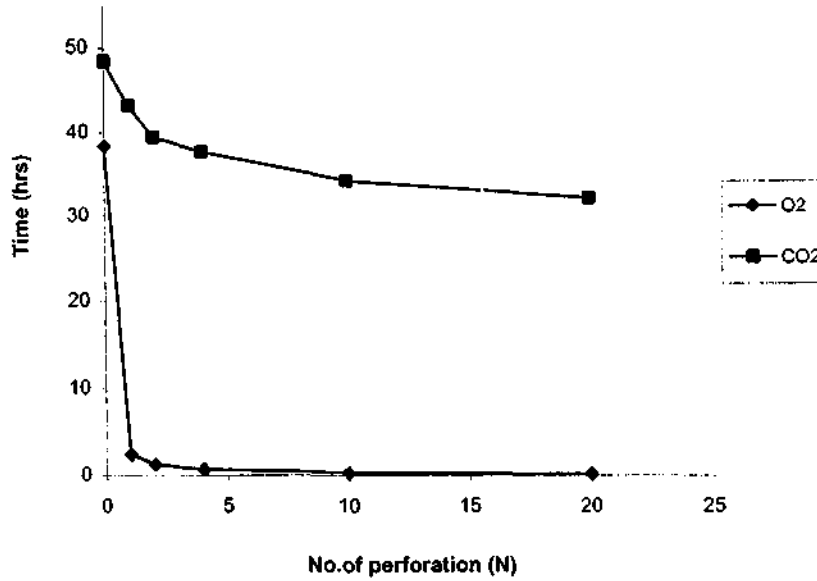


Fig 4.41 Predicted steady state times for O₂ and CO₂ in LD-80 film

(O₂: 3-5 percent, CO₂: 5-10 percent) of these gases which would prevent development of off flavours in mangoes (Yahia and Kader 1997). Similar trends of O₂ concentration were found in S-60 film. Again, perforations had more effect on gas concentration in S-60 film than LD-80. This was because perforation reduced the effect of type of film and diffusive path length (=thicknesses of film) is more important. Gonzalez *et al.* (1997) reported steady state O₂ and CO₂ levels of about 3.0-3.5 and 12-14 percent respectively in 112 gauge non-perforated LDPE film wrapped mangoes. These findings are in conformity with our results keeping in view that actual thickness of LD-80 film in our case is around 120 gauge. Similar results were reported by Fishman *et al.* (1996). Perforations resulted in drastically reducing the steadystate times of O₂ gas but further increase in number of perforations did not much effected the steadystate times of O₂ gas. The effect of increase in number of perforations on steadystate times of CO₂ was much lower than O₂ gas and it further decreased as the number of perforations increased (Table 4.38 and Fig.4.41).

SUMMARY AND CONCLUSIONS

Mango, the king of fruits, constitutes a major part of the total fruit production in India. Because of lack of adequate post-harvest technologies to keep it afresh during transit for longer durations and subsequent storage not much of the quantity is exported from India in spite of being leading mango producer in the world. So bulk of the production is consumed in the domestic market. Keeping in view the above points, the present investigation was undertaken with the specific objectives as listed earlier. The mangoes were harvested at mature green but unripe stage, graded, treated chemically, air dried and packed in 7 different films both perforated and non-perforated. These film wrapped mangoes were stored under three different storage environments and quality of mangoes was observed, to identify the best packaging film. Simulated transportation studies were also carried out to determine the loss during transit and ripening behaviour of mangoes. The experimental findings were verified with the statistical results. A mathematical model was also developed which gave a relationship between perforation and O_2 , CO_2 and water vapour (RH) concentrations within the package as effected by the variable ambient environment. The model predictions were verified with the experimental findings. The following conclusions were drawn:

1. PLW, TSS, pH, decay, shrinkage, TSS/acid ratio and colour change increased with the duration of storage while firmness and acidity followed a reversed trend.
2. Spoilage was mainly due to shrinkage in RT storage while in other two storages, it was mainly due to rotting with stem end rot as the main disease.
3. The rate of weight loss decreased with the thicknesses of the film but increased with the level of perforations. Rate of weight loss was lower in HDPE compared to LDPE and S-60 films treatments. Rate of weight loss was highest in RT storage followed by B&S storage (\approx 50 percent of RT) and lowest in cold storage (\approx 20%) in all the treatments.
4. Firmness increased with the thickness of the film, particularly in non-perforated treatments but it decreased with the level of perforations. Firmness was higher in LDPE than HDPE and S-60 film treatments. Firmness was lowest in RT, followed by B&S storage and highest in cold storage. Firmness was higher in wrapped treatments than control in RT and B&S storage, however the trend was reversed in cold storage.
5. Perforated treatments had higher change in TSS as well as higher peak values of TSS than non-perforated treatments irrespective of type of store. Average peak value of TSS in LDPE films was higher than HDPE films but comparable to S-60 films. The TSS was slightly lower in B&S storage than RT storage.
6. Change in pH decreased with the thicknesses of the film in RT as well as B&S storage while the trend was reversed in cold storage. Change in pH was

slower in non-perforated treatments than perforated treatments. Variation of pH was significantly higher in HDPE than LDPE and S-60 films. The HDPE film treatments crossed the threshold limit of pH = 5.50 earlier than LDPE and S-60 films. Change of pH in B&S storage was slower than RT while pH remained quite low than threshold limit in cold storage.

7. Decay increased with the level of perforations with least decay in non-perforated treatments but it decreased with thicknesses of the films in LDPE films but no-definite trend was found in HDPE films. The LDPE film treatments in general and LD-80 film in particular recorded the lowest decay as compared to other treatments in all the storages.
8. Shrinkage decreased with the thicknesses of the film but increased with the level of perforations. No shrinkage was found in B&S as well as cold storages and in non-perforated treatment of RT storage as well.
9. Maximum decrease in acidity was found in treatments with highest level of perforations closely followed by next level of perforations and least in non-perforated treatments. Treatments with 5.4×10^{-3} and 1.08×10^{-2} percent area of perforations resulted in optimum level of TSS/acid ratio in non-refrigerated and refrigerated storages respectively. The S-60 film treatments did not differ much in their TSS/acid ratio. The TSS/acid ratio was slightly lower in RT than B&S storage. But cold storage resulted in too low value of TSS/acid ratio.
10. Colour change increased with level of perforations but decreased with the thicknesses of the film. The colour remained green in all the treatments of cold storage throughout entire period of storage. Perforated treatments

(lowest level) were best in retaining excellent colour and showed marked superiority in appearance over other treatments.

11. Shifting from traditional wooden boxes to CFB boxes/plastic crate would entail approx. 25-30 and 50 percent reduction in transportation loss in non-wrapped and wrapped fruits respectively. Again shifting from non-wrapping to wrapping would result in 50, 70 and 60 percent reduction in transportation losses in wooden boxes, CFB boxes and plastic crates respectively. The duration of transportation, treatments and type of packages had significant effect on transportation loss.
12. The LD-80 film was found to be best packaging film in retaining desirable quality of mangoes for about 18-20 days.
13. The CO₂ permeability of LD-80 film was much higher than O₂ permeability.
14. Perforations resulted in more transmission rate of O₂ than CO₂ without much effecting the RH within the package. Exchange of gases through perforations accounted for 97-98 percent while film had 2-3 percent of total gas exchange. In non-perforated treatments, it is the type of film that effected the gas exchange while in perforated treatments, on the other hand, it is the thicknesses of the film and more importantly area of perforations that matter much. Perforations resulted in drastically reducing the steady state times of O₂ gas while it did not much effected the steady state times of CO₂ gas.
15. The increase in number of perforations and decrease in ambient RH resulted in decrease in RH within the package but it remained above 95 percent. Perforations did not effect much the steadystate times of RH.

16. A perforation area of around 2.7×10^{-3} percent would give optimum levels of O_2 and CO_2 concentrations which will prevent the development of off flavours in the packaged mangoes and can maintain RH above 95 percent.

Suggestions for future studies:

1. The best packaging film (LD-80) could be tested to evaluate its effects on quality and shelf life of other varieties of mangoes.
2. The organoleptic tests needed to be conducted on packaging and storage of mangoes in LD-80 films.
3. Model has predicted a perforation area of $\approx 2.7 \times 10^{-3}$ percent giving optimum levels of O_2 and CO_2 concentrations which would prevent the development of off flavours in the packed mangoes. There is a need to conduct experiments by decreasing the diameter of perforations below 1.1mm and increasing the number of perforations keeping area of perforations same.
4. TSS/acid ratio need to be estimated in mangoes packed in best polymeric film (LD-80) with an area of perforation (model prediction) of about 2.7×10^{-3} percent.

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APPENDICES

APPENDIX - A

Table A1 Physiological loss in weight under room temperature storage conditions

| Storage Period. | Treatment replications | | | | | | | | | | | | | | |
|--------------------|------------------------|-------|-------|-------|-------|------------------|-------|-------|-------|-------|----------------------|-------|-------|-------|-------|
| | R1 | R2 | R3 | R4 | AVG. | R1 | R2 | R3 | R4 | AVG. | R1 | R2 | R3 | R4 | AVG. |
| | LD-40(T0) | | | | | HD-40(T0) | | | | | S-60(T0) | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 1.71 | 1.16 | 1.62 | 1.69 | 1.55 | 0.50 | 0.68 | 0.99 | 1.07 | 0.81 | 0.92 | 1.12 | 0.90 | 0.67 | 0.90 |
| 7 | 4.32 | 2.01 | 2.57 | 3.57 | 3.12 | 1.23 | 1.78 | 2.49 | 2.60 | 2.03 | 1.93 | 1.93 | 2.12 | 1.90 | 1.97 |
| 10 | 6.11 | 2.86 | 3.53 | 5.35 | 4.46 | 2.26 | 2.96 | 4.00 | 4.66 | 3.47 | 2.73 | 2.58 | 3.06 | 2.53 | 2.72 |
| 13 | 7.29 | 3.57 | 4.40 | 6.45 | 5.43 | 3.73 | 3.94 | 5.08 | 6.00 | 4.69 | 3.54 | 3.81 | 3.94 | 3.29 | 3.65 |
| 16 | 8.31 | 4.38 | 5.32 | 7.72 | 6.43 | 4.98 | 4.92 | 6.26 | 7.20 | 5.84 | 4.39 | 4.46 | 4.73 | 3.85 | 4.36 |
| 19 | 9.42 | 5.59 | 6.48 | 9.31 | 7.70 | 5.97 | 5.64 | 7.27 | 8.05 | 6.74 | 5.13 | 4.97 | 5.45 | 4.84 | 5.10 |
| 22 | 10.39 | 7.42 | 7.55 | 10.28 | 8.91 | 6.91 | 6.66 | 8.23 | 9.49 | 7.82 | 5.69 | 5.51 | 6.23 | 5.37 | 5.70 |
| | LD-40(T1) | | | | | HD-40(T1) | | | | | S-60(T1) | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 3.15 | 2.20 | 2.84 | 2.47 | 2.66 | 4.27 | 4.42 | 4.07 | 4.85 | 4.40 | 2.90 | 3.07 | 2.82 | 2.90 | 2.92 |
| 7 | 6.52 | 5.97 | 5.80 | 6.14 | 6.11 | 7.04 | 7.54 | 6.81 | 7.81 | 7.30 | 7.03 | 6.43 | 6.87 | 7.32 | 6.91 |
| 10 | 11.45 | 9.79 | 10.26 | 10.51 | 10.50 | 9.88 | 10.43 | 9.80 | 11.01 | 10.28 | 10.47 | 10.69 | 10.92 | 10.92 | 10.75 |
| 13 | 15.08 | 13.84 | 13.59 | 14.13 | 14.16 | 11.92 | 12.67 | 11.98 | 13.27 | 12.46 | 13.66 | 13.58 | 13.62 | 14.27 | 13.78 |
| 16 | 18.80 | 17.16 | 17.12 | 17.34 | 17.60 | 14.19 | 15.46 | 14.87 | 16.35 | 15.22 | 17.04 | 17.55 | 17.16 | 17.71 | 17.36 |
| 19 | 21.30 | 19.54 | 19.49 | 19.74 | 20.02 | 17.11 | 18.39 | 18.39 | 20.55 | 18.61 | | | | | |
| 22 | 24.15 | 22.07 | 21.81 | 22.19 | 22.55 | 20.32 | 21.84 | 22.10 | 23.71 | 21.99 | | | | | |
| | LD-40(T2) | | | | | HD-40(T2) | | | | | S-60(T2) | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 3.88 | 2.77 | 2.09 | 3.20 | 2.98 | 5.25 | 5.36 | 5.22 | 4.90 | 5.18 | 3.36 | 3.47 | 3.90 | 3.50 | 3.55 |
| 7 | 8.63 | 6.81 | 4.75 | 7.67 | 6.97 | 8.73 | 8.53 | 8.53 | 8.12 | 8.48 | 7.74 | 7.96 | 7.63 | 7.43 | 7.69 |
| 10 | 13.96 | 12.46 | 9.18 | 13.22 | 12.20 | 12.12 | 11.94 | 12.12 | 11.59 | 11.95 | 11.44 | 11.69 | 10.93 | 10.60 | 11.16 |
| 13 | 18.63 | 15.25 | 13.15 | 16.60 | 15.91 | 14.41 | 14.30 | 14.61 | 13.96 | 14.32 | 14.95 | 15.35 | 15.17 | 14.68 | 15.04 |
| 16 | 22.37 | 18.98 | 16.88 | 19.94 | 19.54 | 16.97 | 16.97 | 17.30 | 16.36 | 16.90 | 17.65 | 18.04 | 18.61 | 17.67 | 17.99 |
| 19 | 24.44 | 21.49 | 20.06 | 22.61 | 22.15 | 20.33 | 20.24 | 19.97 | 19.20 | 19.94 | | | | | |
| 22 | 27.72 | 22.99 | 21.31 | 24.45 | 24.12 | 22.60 | 22.57 | 22.50 | 21.55 | 22.31 | | | | | |
| | LD-40(T3) | | | | | HD-40(T3) | | | | | S-60(T3) | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 3.32 | 3.71 | 2.86 | 3.14 | 3.26 | 6.35 | 6.21 | 6.07 | 6.04 | 6.17 | 4.42 | 4.37 | 4.25 | 4.67 | 4.43 |
| 7 | 7.73 | 8.29 | 7.30 | 7.63 | 7.74 | 10.22 | 10.24 | 10.12 | 10.23 | 10.20 | 9.86 | 9.48 | 9.63 | 10.52 | 9.87 |
| 10 | 13.36 | 13.91 | 12.36 | 13.43 | 13.27 | 14.14 | 13.76 | 14.27 | 14.36 | 14.13 | 14.39 | 13.64 | 14.05 | 15.38 | 14.36 |
| 13 | 17.84 | 18.06 | 16.24 | 17.66 | 17.45 | 17.00 | 16.59 | 17.11 | 17.16 | 16.97 | 18.28 | 17.25 | 17.97 | 19.73 | 18.31 |
| 16 | 22.55 | 22.35 | 19.94 | 22.03 | 21.72 | 19.92 | 20.04 | 19.78 | 20.13 | 19.97 | 20.78 | 19.55 | 20.33 | 22.39 | 20.76 |
| 19 | 25.67 | 25.07 | 22.64 | 24.58 | 24.49 | 23.27 | 24.33 | 23.47 | 23.72 | 23.70 | | | | | |
| 22 | 28.94 | 28.29 | 25.71 | 27.87 | 27.70 | 24.18 | 25.63 | 24.59 | 24.75 | 24.79 | | | | | |
| | LD-60(T0) | | | | | HD-60(T0) | | | | | UNWRAPPED (T) | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 0.97 | 1.14 | 0.91 | 1.36 | 1.09 | 0.94 | 0.77 | 0.54 | 0.45 | 0.67 | 5.06 | 4.41 | 4.94 | 5.31 | 4.93 |
| 7 | 2.17 | 2.13 | 2.10 | 2.84 | 2.31 | 2.21 | 2.00 | 1.16 | 1.14 | 1.63 | 10.78 | 9.90 | 11.07 | 11.21 | 10.74 |
| 10 | 3.16 | 3.04 | 3.13 | 4.04 | 3.34 | 3.62 | 3.30 | 1.92 | 2.40 | 2.81 | 16.63 | 15.37 | 17.65 | 17.96 | 16.90 |
| 13 | 4.09 | 3.86 | 4.24 | 5.10 | 4.33 | 4.66 | 4.36 | 2.54 | 3.22 | 3.70 | | | | | |
| 16 | 4.99 | 4.67 | 5.30 | 6.13 | 5.27 | 5.45 | 5.29 | 3.14 | 3.98 | 4.47 | | | | | |
| 19 | 5.79 | 5.19 | 6.03 | 6.86 | 5.97 | 6.38 | 6.22 | 3.65 | 4.85 | 5.23 | | | | | |
| 22 | 6.46 | 5.74 | 6.70 | 7.65 | 6.64 | 6.61 | 6.75 | 4.21 | 5.32 | 5.72 | | | | | |
| 25 | 7.01 | 6.32 | 7.26 | 8.36 | 7.24 | 7.10 | 7.23 | 4.75 | 5.86 | 6.24 | | | | | |
| | LD-60(T1) | | | | | HD-60(T1) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 2.79 | 2.04 | 2.58 | 2.81 | 2.65 | 2.28 | 3.27 | 2.05 | 2.39 | 2.50 | | | | | |
| 7 | 6.54 | 5.52 | 6.40 | 7.13 | 6.40 | 5.62 | 7.65 | 5.86 | 6.13 | 6.32 | | | | | |
| 10 | 10.62 | 9.27 | 11.27 | 11.44 | 10.65 | 8.89 | 12.39 | 10.28 | 10.57 | 10.53 | | | | | |
| 13 | 13.81 | 12.24 | 14.90 | 14.91 | 13.97 | 11.65 | 16.02 | 13.68 | 14.02 | 13.84 | | | | | |
| 16 | 17.03 | 15.38 | 18.40 | 18.40 | 17.30 | 14.27 | 19.52 | 17.01 | 17.32 | 17.03 | | | | | |
| 19 | 19.37 | 17.46 | 21.05 | 20.73 | 19.65 | 16.16 | 21.94 | 19.20 | 19.58 | 19.22 | | | | | |
| 22 | 21.76 | 20.49 | 23.41 | 23.30 | 22.24 | 18.19 | 24.91 | 21.49 | 21.95 | 21.64 | | | | | |
| 25 | 24.24 | 22.33 | 25.28 | 24.88 | 24.18 | | | | | | | | | | |

| t | R1 | R2 | R3 | R4 | AVG. | R1 | R2 | R3 | R4 | AVG. | R1 | R2 | R3 | R4 | AVG. |
|----|------------------|-------|-------|-------|-------|------------------|-------|-------|-------|-------|----|----|----|----|------|
| | LD-60(T2) | | | | | HD-60(T2) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 2.36 | 3.50 | 2.68 | 2.75 | 2.82 | 2.85 | 2.42 | 2.66 | 2.64 | 2.64 | | | | | |
| 7 | 5.57 | 8.52 | 6.28 | 7.04 | 6.85 | 6.78 | 6.43 | 6.71 | 7.14 | 6.77 | | | | | |
| 10 | 9.98 | 14.48 | 10.81 | 12.24 | 11.88 | 11.31 | 10.47 | 10.82 | 11.30 | 10.98 | | | | | |
| 13 | 13.33 | 18.90 | 14.04 | 15.84 | 15.53 | 14.54 | 13.17 | 13.64 | 14.82 | 14.04 | | | | | |
| 16 | 16.72 | 23.25 | 17.67 | 19.58 | 19.30 | 17.92 | 16.13 | 16.41 | 18.56 | 17.26 | | | | | |
| 19 | 18.04 | 26.63 | 20.37 | 22.16 | 21.80 | 20.36 | 18.35 | 18.56 | 20.81 | 19.52 | | | | | |
| 22 | 18.99 | 27.87 | 21.41 | 23.61 | 22.97 | 22.70 | 20.56 | 20.92 | 23.53 | 21.93 | | | | | |
| 25 | 20.30 | 29.64 | 22.98 | 24.92 | 24.46 | | | | | | | | | | |
| | LD-60(T3) | | | | | HD-60(T3) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 3.30 | 2.75 | 3.40 | 3.54 | 3.25 | 3.01 | 2.61 | 3.68 | 2.87 | 3.04 | | | | | |
| 7 | 7.29 | 6.72 | 7.91 | 8.91 | 7.71 | 7.40 | 6.02 | 7.74 | 7.76 | 7.23 | | | | | |
| 10 | 12.45 | 11.12 | 13.37 | 14.33 | 12.82 | 12.23 | 10.27 | 12.69 | 13.62 | 12.20 | | | | | |
| 13 | 16.37 | 14.51 | 17.57 | 18.62 | 16.77 | 15.26 | 14.29 | 16.37 | 17.89 | 15.96 | | | | | |
| 16 | 20.08 | 17.86 | 21.72 | 22.59 | 20.56 | 18.61 | 16.88 | 20.45 | 22.01 | 19.49 | | | | | |
| 19 | 22.71 | 20.35 | 24.78 | 25.59 | 23.36 | 21.02 | 19.28 | 23.36 | 24.68 | 22.09 | | | | | |
| 22 | 25.44 | 22.71 | 27.69 | 28.53 | 26.09 | 23.54 | 21.73 | 25.69 | 27.09 | 24.51 | | | | | |
| | LD-80(T0) | | | | | HD-80(T0) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 0.54 | 0.34 | 0.39 | 0.51 | 0.45 | 0.52 | 0.41 | 0.35 | 0.36 | 0.41 | | | | | |
| 7 | 1.24 | 0.97 | 1.18 | 1.26 | 1.16 | 1.10 | 0.80 | 0.70 | 0.78 | 0.85 | | | | | |
| 10 | 1.99 | 1.85 | 2.18 | 2.18 | 2.05 | 1.96 | 1.74 | 1.55 | 2.02 | 1.82 | | | | | |
| 13 | 2.78 | 2.63 | 3.03 | 2.88 | 2.83 | 2.67 | 2.59 | 2.54 | 3.27 | 2.77 | | | | | |
| 16 | 3.65 | 3.41 | 3.85 | 3.62 | 3.63 | 3.03 | 3.01 | 3.53 | 3.84 | 3.35 | | | | | |
| 19 | 4.30 | 3.96 | 4.53 | 4.29 | 4.27 | 3.48 | 3.68 | 4.91 | 4.59 | 4.16 | | | | | |
| 22 | 5.03 | 4.61 | 5.33 | 5.12 | 5.02 | 3.87 | 4.27 | 5.68 | 5.37 | 4.80 | | | | | |
| 25 | 6.05 | 5.49 | 6.04 | 5.71 | 5.82 | 4.48 | 4.81 | 6.23 | 5.94 | 5.37 | | | | | |
| 28 | 6.98 | 7.05 | 6.80 | 6.30 | 6.78 | | | | | | | | | | |
| | LD-80(T1) | | | | | HD-80(T1) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 2.61 | 2.28 | 2.81 | 2.78 | 2.62 | 2.24 | 2.48 | 2.58 | 2.96 | 2.57 | | | | | |
| 7 | 6.20 | 5.38 | 7.09 | 5.76 | 6.11 | 5.33 | 5.96 | 6.55 | 7.29 | 6.28 | | | | | |
| 10 | 10.23 | 9.83 | 11.86 | 9.87 | 10.45 | 9.58 | 10.46 | 10.40 | 11.28 | 10.43 | | | | | |
| 13 | 13.09 | 12.87 | 15.36 | 13.40 | 13.68 | 12.29 | 13.45 | 13.00 | 14.70 | 13.36 | | | | | |
| 16 | 15.99 | 16.29 | 18.87 | 16.58 | 16.93 | 14.86 | 16.07 | 15.36 | 17.48 | 15.94 | | | | | |
| 19 | 18.09 | 18.59 | 22.51 | 19.09 | 19.57 | 16.51 | 17.85 | 17.02 | 19.49 | 17.72 | | | | | |
| 22 | 20.33 | 21.39 | 24.78 | 21.46 | 21.99 | 18.31 | 19.63 | 18.72 | 21.48 | 19.54 | | | | | |
| 25 | 22.59 | 23.76 | 26.94 | 23.79 | 24.27 | | | | | | | | | | |
| | LD-80(T2) | | | | | HD-80(T2) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 2.90 | 3.11 | 2.55 | 2.53 | 2.77 | 2.23 | 2.40 | 2.36 | 2.66 | 2.41 | | | | | |
| 7 | 7.27 | 7.11 | 6.45 | 6.57 | 6.85 | 5.81 | 6.37 | 5.88 | 6.63 | 6.17 | | | | | |
| 10 | 12.08 | 11.13 | 10.55 | 10.68 | 11.11 | 10.92 | 11.13 | 11.13 | 11.03 | 11.05 | | | | | |
| 13 | 15.50 | 14.55 | 13.82 | 13.58 | 14.36 | 12.67 | 14.25 | 14.36 | 13.43 | 13.68 | | | | | |
| 16 | 18.86 | 18.00 | 16.78 | 16.61 | 17.58 | 15.53 | 17.36 | 17.44 | 16.02 | 16.59 | | | | | |
| 19 | 21.51 | 20.32 | 19.15 | 18.72 | 19.92 | 17.63 | 19.51 | 19.67 | 18.01 | 18.70 | | | | | |
| 22 | 24.17 | 23.10 | 21.59 | 20.89 | 22.44 | 19.85 | 21.59 | 21.93 | 20.38 | 20.94 | | | | | |
| 25 | 26.75 | 25.80 | 24.07 | 23.26 | 24.97 | | | | | | | | | | |
| | LD-80(T3) | | | | | HD-80(T3) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 2.91 | 3.80 | 2.51 | 3.20 | 3.11 | 3.50 | 3.21 | 2.81 | 2.93 | 3.11 | | | | | |
| 7 | 7.02 | 8.43 | 6.25 | 7.81 | 7.38 | 8.41 | 7.68 | 7.36 | 7.39 | 7.71 | | | | | |
| 10 | 12.83 | 13.75 | 10.26 | 12.93 | 12.44 | 12.77 | 12.19 | 12.30 | 12.00 | 12.32 | | | | | |
| 13 | 17.31 | 18.15 | 13.35 | 16.86 | 16.42 | 16.39 | 15.13 | 15.94 | 15.39 | 15.71 | | | | | |
| 16 | 21.49 | 22.53 | 16.58 | 20.51 | 20.28 | 20.15 | 18.36 | 19.85 | 18.67 | 19.26 | | | | | |
| 19 | 24.72 | 25.48 | 18.94 | 23.35 | 23.12 | 22.86 | 20.81 | 22.57 | 21.03 | 21.82 | | | | | |
| 22 | 28.13 | 28.37 | 21.23 | 26.12 | 25.96 | 25.46 | 23.28 | 25.46 | 23.52 | 24.43 | | | | | |

Table A2 Physiological loss in weight under brick & sand storage conditions

| Storage Period, t | Treatment replications | | | | | | | | | | | | | | |
|-------------------|------------------------|-------|-------|-------|-------|-------------------|-------|-------|-------|-------|------------------------|-------|-------|-------|-------|
| | R1 | R2 | R3 | R4 | AVG. | R1 | R2 | R3 | R4 | AVG. | R1 | R2 | R3 | R4 | AVG. |
| | LD--40(T0) | | | | | HD--40(T0) | | | | | S-60(T0) | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 0.67 | 0.68 | 0.70 | 0.75 | 0.70 | 0.71 | 0.68 | 0.87 | 0.42 | 0.67 | 0.64 | 0.73 | 0.87 | 0.66 | 0.72 |
| 7 | 1.17 | 1.56 | 1.67 | 1.49 | 1.47 | 1.33 | 1.25 | 1.51 | 1.12 | 1.30 | 1.02 | 1.40 | 1.37 | 1.18 | 1.24 |
| 10 | 1.75 | 2.13 | 2.38 | 2.09 | 2.09 | 1.86 | 1.87 | 2.11 | 1.74 | 1.89 | 1.43 | 2.03 | 1.83 | 1.82 | 1.78 |
| 13 | 2.54 | 2.83 | 3.08 | 2.73 | 2.79 | 2.41 | 2.81 | 2.80 | 2.38 | 2.60 | 1.75 | 2.50 | 2.13 | 2.30 | 2.17 |
| 16 | 3.33 | 3.86 | 3.49 | 3.37 | 3.46 | 3.14 | 3.57 | 3.49 | 2.95 | 3.29 | 2.14 | 3.14 | 2.52 | 2.91 | 2.68 |
| 19 | 4.07 | 4.39 | 4.64 | 3.82 | 4.23 | 4.05 | 4.15 | 4.19 | 3.51 | 3.97 | 3.16 | 3.75 | 3.21 | 3.54 | 3.41 |
| 22 | 4.53 | 5.33 | 5.37 | 4.29 | 4.88 | 4.64 | 4.74 | 4.78 | 4.13 | 4.57 | 5.27 | 4.19 | 3.58 | 4.02 | 4.27 |
| 25 | 5.35 | 6.15 | 6.07 | 5.03 | 5.65 | | | | | | 5.75 | 4.85 | 4.13 | 4.65 | 4.84 |
| | LD-40(T1) | | | | | HD--40(T1) | | | | | S-60(T1) | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 1.61 | 1.68 | 1.77 | 1.45 | 1.63 | 2.17 | 1.84 | 1.63 | 1.27 | 1.73 | 1.65 | 1.45 | 1.69 | 1.85 | 1.66 |
| 7 | 3.62 | 3.75 | 3.98 | 3.88 | 3.81 | 3.31 | 3.20 | 3.33 | 2.99 | 3.21 | 3.51 | 3.71 | 3.84 | 3.50 | 3.64 |
| 10 | 5.38 | 5.30 | 5.98 | 5.71 | 5.59 | 4.96 | 5.01 | 5.00 | 4.37 | 4.83 | 5.25 | 5.22 | 5.18 | 5.45 | 5.28 |
| 13 | 7.09 | 6.78 | 7.74 | 7.57 | 7.30 | 6.49 | 6.80 | 6.69 | 5.59 | 6.39 | 7.22 | 6.90 | 7.38 | 6.87 | 7.09 |
| 16 | 8.66 | 8.45 | 9.29 | 9.44 | 8.96 | 7.95 | 8.30 | 8.34 | 6.74 | 7.83 | 8.74 | 9.18 | 9.01 | 8.88 | 8.95 |
| 19 | 9.94 | 9.72 | 10.39 | 11.35 | 10.35 | 9.03 | 9.40 | 9.56 | 8.04 | 9.01 | 10.41 | 10.23 | 9.77 | 9.89 | 10.07 |
| 22 | 10.93 | 10.69 | 11.25 | 12.32 | 11.30 | 9.85 | 10.31 | 10.61 | 8.87 | 9.91 | 11.16 | 10.93 | 10.48 | 10.67 | 10.81 |
| | LD-40(T2) | | | | | HD--40(T2) | | | | | S-60(T2) | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 1.87 | 1.69 | 2.01 | 1.76 | 1.83 | 2.13 | 1.50 | 2.33 | 2.00 | 1.99 | 1.75 | 1.69 | 1.75 | 2.27 | 1.87 |
| 7 | 3.80 | 4.03 | 3.97 | 4.06 | 3.96 | 3.49 | 2.89 | 4.03 | 3.50 | 3.48 | 3.64 | 3.97 | 3.46 | 3.86 | 3.73 |
| 10 | 6.27 | 5.83 | 4.64 | 5.74 | 5.62 | 5.28 | 5.01 | 6.00 | 5.58 | 5.46 | 5.24 | 5.80 | 5.13 | 5.48 | 5.41 |
| 13 | 7.42 | 7.57 | 6.85 | 7.32 | 7.29 | 6.41 | 6.48 | 7.41 | 7.35 | 6.91 | 7.17 | 7.54 | 6.69 | 7.44 | 7.21 |
| 16 | 9.14 | 9.24 | 8.95 | 8.78 | 9.02 | 7.95 | 8.07 | 8.92 | 8.69 | 8.41 | 9.37 | 9.14 | 8.74 | 8.88 | 9.03 |
| 19 | 10.19 | 10.25 | 10.45 | 10.04 | 10.23 | 9.05 | 9.04 | 10.11 | 9.60 | 9.45 | 10.55 | 10.22 | 9.90 | 9.97 | 10.16 |
| 22 | 11.25 | 11.27 | 11.39 | 11.32 | 11.31 | 9.52 | 9.42 | 10.80 | 9.60 | 9.91 | 11.81 | 11.73 | 11.45 | 11.49 | 11.62 |
| | LD--40(T3) | | | | | HD--40(T3) | | | | | S-60(T3) | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 2.35 | 2.86 | 2.17 | 2.15 | 2.38 | 1.76 | 2.05 | 2.38 | 2.36 | 2.14 | 2.06 | 2.01 | 2.24 | 2.05 | 2.09 |
| 7 | 4.43 | 5.38 | 4.20 | 4.44 | 4.61 | 4.84 | 3.93 | 4.21 | 4.22 | 4.30 | 3.39 | 4.01 | 4.10 | 4.09 | 3.90 |
| 10 | 6.53 | 7.86 | 6.10 | 6.41 | 6.72 | 7.53 | 5.96 | 6.28 | 6.48 | 6.56 | 5.53 | 5.75 | 5.98 | 5.91 | 5.79 |
| 13 | 8.62 | 9.91 | 7.73 | 8.24 | 8.62 | 9.40 | 7.30 | 7.73 | 7.97 | 8.10 | 7.24 | 7.34 | 7.31 | 7.63 | 7.38 |
| 16 | 10.30 | 11.67 | 9.34 | 10.03 | 10.34 | 11.68 | 9.09 | 9.33 | 9.82 | 9.98 | 9.66 | 9.10 | 9.11 | 9.15 | 9.25 |
| 19 | 11.74 | 13.18 | 10.66 | 11.57 | 11.79 | 12.62 | 10.36 | 10.29 | 11.25 | 11.13 | 10.94 | 10.99 | 10.19 | 10.37 | 10.63 |
| 22 | 12.93 | 14.36 | 11.67 | 12.64 | 12.90 | 13.55 | 11.53 | 11.40 | 12.46 | 12.24 | 12.01 | 12.20 | 11.52 | 11.68 | 11.85 |
| | LD--60(T0) | | | | | HD--60(T0) | | | | | Non-wrapped (T) | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 0.81 | 0.46 | 0.85 | 0.56 | 0.67 | 0.93 | 0.51 | 0.47 | 0.64 | 0.64 | 2.08 | 2.05 | 2.47 | 2.60 | 2.30 |
| 7 | 1.76 | 0.94 | 1.52 | 1.05 | 1.32 | 1.63 | 1.01 | 0.94 | 1.29 | 1.22 | 4.75 | 5.36 | 5.72 | 5.91 | 5.44 |
| 10 | 2.52 | 1.50 | 2.23 | 1.57 | 1.96 | 2.29 | 1.46 | 1.35 | 1.77 | 1.71 | 7.86 | 8.05 | 9.14 | 9.33 | 8.59 |
| 13 | 3.25 | 2.13 | 2.98 | 2.00 | 2.59 | 3.32 | 1.88 | 1.85 | 2.32 | 2.34 | | | | | |
| 16 | 3.89 | 2.75 | 3.98 | 2.70 | 3.33 | 4.19 | 2.56 | 2.47 | 2.83 | 3.01 | | | | | |
| 19 | 4.49 | 3.10 | 4.86 | 3.09 | 3.89 | 4.64 | 2.96 | 2.94 | 3.49 | 3.51 | | | | | |
| 22 | 5.07 | 3.47 | 5.29 | 3.52 | 4.34 | 5.25 | 3.44 | 3.52 | 4.07 | 4.07 | | | | | |
| 25 | 5.77 | 3.99 | 5.75 | 4.09 | 4.90 | 5.72 | 4.04 | 4.18 | 4.72 | 4.67 | | | | | |
| 28 | 6.34 | 4.68 | 6.22 | 4.86 | 5.52 | | | | | | | | | | |
| | LD--60(T1) | | | | | HD--60(T1) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 1.59 | 1.50 | 1.57 | 1.61 | 1.57 | 1.58 | 1.61 | 1.54 | 1.93 | 1.66 | | | | | |
| 7 | 3.67 | 3.37 | 3.46 | 3.70 | 3.55 | 3.29 | 2.89 | 3.16 | 3.19 | 3.13 | | | | | |
| 10 | 5.53 | 5.47 | 4.85 | 5.80 | 5.41 | 4.92 | 4.67 | 4.78 | 4.53 | 4.73 | | | | | |
| 13 | 6.98 | 7.27 | 6.50 | 7.42 | 7.04 | 6.29 | 6.13 | 6.12 | 5.57 | 6.03 | | | | | |
| 16 | 8.61 | 8.66 | 7.99 | 9.00 | 8.56 | 7.71 | 7.68 | 7.49 | 6.95 | 7.46 | | | | | |
| 19 | 9.82 | 9.98 | 9.14 | 10.14 | 9.77 | 8.48 | 8.51 | 8.26 | 7.73 | 8.25 | | | | | |
| 22 | 10.81 | 10.94 | 9.99 | 11.10 | 10.71 | 9.11 | 9.33 | 8.98 | 8.57 | 9.00 | | | | | |
| 25 | 11.66 | 11.94 | 10.95 | 11.98 | 11.63 | | | | | | | | | | |

| I | R1 | R2 | R3 | R4 | AVG. | R1 | R2 | R3 | R4 | AVG. | R1 | R2 | R3 | R4 | AVG. |
|----|------------------|-------|-------|-------|-------|------------------|-------|-------|-------|-------|----|----|----|----|------|
| | LD-80(T2) | | | | | HD-80(T2) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 2.03 | 1.73 | 1.99 | 1.45 | 1.80 | 1.73 | 1.58 | 2.07 | 1.92 | 1.83 | | | | | |
| 7 | 4.42 | 3.55 | 4.20 | 3.54 | 3.93 | 2.84 | 3.12 | 3.76 | 3.35 | 3.27 | | | | | |
| 10 | 5.88 | 4.61 | 6.15 | 5.46 | 5.52 | 4.17 | 5.02 | 6.39 | 5.14 | 5.18 | | | | | |
| 13 | 7.39 | 6.94 | 7.77 | 6.82 | 7.23 | 5.32 | 6.27 | 7.29 | 6.34 | 6.30 | | | | | |
| 16 | 9.18 | 8.51 | 9.51 | 8.55 | 8.94 | 6.82 | 7.80 | 8.91 | 7.98 | 7.83 | | | | | |
| 19 | 10.23 | 9.81 | 10.77 | 9.70 | 10.13 | 7.43 | 8.87 | 9.83 | 8.91 | 8.76 | | | | | |
| 22 | 11.14 | 11.13 | 11.57 | 10.63 | 11.12 | 7.96 | 9.58 | 10.44 | 9.52 | 9.38 | | | | | |
| 25 | 12.16 | 11.93 | 12.55 | 11.46 | 12.03 | | | | | | | | | | |
| | LD-80(T3) | | | | | HD-80(T3) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 1.83 | 2.04 | 1.99 | 1.74 | 1.90 | 1.17 | 2.07 | 2.17 | 1.85 | 1.81 | | | | | |
| 7 | 4.07 | 4.71 | 3.94 | 4.02 | 4.19 | 2.76 | 4.27 | 4.66 | 4.30 | 4.00 | | | | | |
| 10 | 6.07 | 6.64 | 5.78 | 6.09 | 6.14 | 4.75 | 6.40 | 6.79 | 6.50 | 6.11 | | | | | |
| 13 | 8.04 | 8.63 | 7.40 | 7.77 | 7.96 | 6.50 | 8.11 | 8.86 | 8.54 | 8.00 | | | | | |
| 16 | 9.74 | 10.42 | 8.90 | 9.37 | 9.61 | 7.98 | 9.67 | 10.71 | 10.33 | 9.67 | | | | | |
| 19 | 11.10 | 11.93 | 10.18 | 10.86 | 11.02 | 9.16 | 11.16 | 12.31 | 11.60 | 11.06 | | | | | |
| 22 | 12.19 | 12.87 | 11.14 | 11.89 | 12.02 | 10.01 | 11.99 | 13.53 | 12.66 | 12.05 | | | | | |
| | LD-80(T0) | | | | | HD-80(T0) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 0.30 | 0.28 | 0.74 | 0.41 | 0.43 | 0.38 | 0.44 | 0.45 | 0.52 | 0.45 | | | | | |
| 7 | 0.68 | 0.62 | 1.52 | 1.00 | 0.96 | 1.06 | 0.77 | 0.82 | 0.86 | 0.88 | | | | | |
| 10 | 1.11 | 1.06 | 2.11 | 1.54 | 1.46 | 1.56 | 1.20 | 1.30 | 1.33 | 1.35 | | | | | |
| 13 | 1.65 | 1.62 | 2.84 | 2.12 | 2.05 | 2.10 | 1.55 | 1.73 | 1.80 | 1.80 | | | | | |
| 16 | 2.09 | 1.95 | 3.56 | 2.74 | 2.59 | 2.79 | 1.95 | 2.32 | 2.36 | 2.35 | | | | | |
| 19 | 2.46 | 2.26 | 4.27 | 3.35 | 3.08 | 3.16 | 2.17 | 2.65 | 2.64 | 2.65 | | | | | |
| 22 | 2.85 | 2.63 | 4.75 | 3.87 | 3.52 | 3.97 | 2.68 | 3.38 | 3.29 | 3.33 | | | | | |
| 25 | 3.35 | 3.10 | 5.31 | 4.52 | 4.07 | 4.50 | 3.14 | 3.81 | 3.79 | 3.81 | | | | | |
| 28 | 3.89 | 3.72 | 5.97 | 5.21 | 4.70 | | | | | | | | | | |
| | LD-80(T1) | | | | | HD-80(T1) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 1.37 | 1.69 | 1.09 | 1.39 | 1.38 | 1.19 | 1.27 | 1.42 | 1.33 | 1.30 | | | | | |
| 7 | 3.62 | 3.67 | -0.25 | 3.90 | 2.74 | 2.54 | 2.89 | 2.89 | 3.02 | 2.83 | | | | | |
| 10 | 5.12 | 5.67 | 4.60 | 5.33 | 5.18 | 3.87 | 4.22 | 4.07 | 4.24 | 4.10 | | | | | |
| 13 | 6.73 | 7.15 | 6.18 | 6.85 | 6.73 | 5.27 | 5.38 | 5.16 | 5.71 | 5.38 | | | | | |
| 16 | 8.18 | 8.63 | 7.60 | 8.30 | 8.18 | 6.50 | 6.69 | 6.27 | 6.91 | 6.59 | | | | | |
| 19 | 9.26 | 9.70 | 8.80 | 9.49 | 9.31 | 7.53 | 7.72 | 7.26 | 7.94 | 7.61 | | | | | |
| 22 | 10.02 | 10.46 | 9.80 | 10.49 | 10.19 | 7.77 | 8.70 | 8.22 | 8.81 | 8.37 | | | | | |
| 25 | 10.74 | 11.24 | 10.63 | 11.38 | 11.00 | | | | | | | | | | |
| | LD-80(T2) | | | | | HD-80(T2) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 1.47 | 1.72 | 1.53 | 1.43 | 1.54 | 1.61 | 1.61 | 1.39 | 1.20 | 1.45 | | | | | |
| 7 | 3.53 | 4.31 | 2.79 | 3.34 | 3.49 | 3.37 | 3.36 | 3.06 | 2.94 | 3.18 | | | | | |
| 10 | 5.27 | 6.04 | 4.31 | 5.01 | 5.16 | 4.74 | 4.71 | 4.08 | 4.40 | 4.48 | | | | | |
| 13 | 7.08 | 7.72 | 5.97 | 6.85 | 6.91 | 6.18 | 6.11 | 6.15 | 5.70 | 6.03 | | | | | |
| 16 | 8.60 | 9.87 | 7.48 | 8.32 | 8.57 | 7.62 | 7.51 | 7.53 | 6.94 | 7.40 | | | | | |
| 19 | 9.87 | 11.10 | 8.56 | 9.58 | 9.78 | 8.80 | 8.50 | 8.61 | 7.87 | 8.45 | | | | | |
| 22 | 10.76 | 12.12 | 9.37 | 10.61 | 10.71 | 9.62 | 9.33 | 9.41 | 8.60 | 9.24 | | | | | |
| 25 | 11.68 | 13.08 | 10.19 | 11.66 | 11.65 | | | | | | | | | | |
| | LD-80(T3) | | | | | HD-80(T3) | | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 1.12 | 2.08 | 1.72 | 1.67 | 1.65 | 1.77 | 1.80 | 1.77 | 1.55 | 1.72 | | | | | |
| 7 | 3.21 | 4.42 | 4.09 | 3.66 | 3.85 | 4.14 | 4.32 | 4.15 | 2.85 | 3.86 | | | | | |
| 10 | 4.66 | 6.37 | 5.78 | 5.15 | 5.49 | 6.08 | 6.48 | 6.07 | 4.78 | 5.85 | | | | | |
| 13 | 6.36 | 8.37 | 7.68 | 6.83 | 7.31 | 7.41 | 8.08 | 7.76 | 6.20 | 7.36 | | | | | |
| 16 | 7.96 | 10.26 | 9.30 | 8.47 | 9.00 | 8.94 | 9.85 | 10.13 | 7.88 | 9.20 | | | | | |
| 19 | 9.35 | 11.66 | 10.62 | 9.55 | 10.30 | 9.70 | 10.76 | 13.57 | 8.69 | 10.68 | | | | | |
| 22 | 10.43 | 12.75 | 11.69 | 10.48 | 11.34 | 10.45 | 11.58 | 14.57 | 9.38 | 11.50 | | | | | |

Table A3 Physiological loss in weight under cold storage conditions

| Storage Period,t | Replications | | | | | | | | | | | |
|---------------------|-------------------|------|------|------|-------------------|------|------|------|------------------------|-------|-------|-------|
| | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. |
| | LD--40(T0) | | | | HD--40(T0) | | | | S--60(T0) | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 0.18 | 0.19 | 0.17 | 0.18 | 0.31 | 0.32 | 0.07 | 0.23 | 0.25 | 0.34 | 0.11 | 0.23 |
| 7 | 0.57 | 0.45 | 0.37 | 0.46 | 0.42 | 0.20 | 0.36 | 0.33 | 0.33 | 0.45 | 0.18 | 0.32 |
| 10 | 0.59 | 0.49 | 0.41 | 0.49 | 0.89 | 0.65 | 0.68 | 0.74 | 0.44 | 0.64 | 0.36 | 0.48 |
| 13 | 0.75 | 0.85 | 0.58 | 0.73 | 1.06 | 0.71 | 0.72 | 0.83 | 0.52 | 0.77 | 0.41 | 0.57 |
| 16 | 1.20 | 1.04 | 0.85 | 1.03 | 1.16 | 0.87 | 0.76 | 0.93 | 0.79 | 1.09 | 0.63 | 0.83 |
| 19 | 1.61 | 1.49 | 1.04 | 1.38 | 1.29 | 1.02 | 0.85 | 1.05 | 0.95 | 1.30 | 0.85 | 1.03 |
| 22 | 1.85 | 1.55 | 1.24 | 1.55 | 1.62 | 1.26 | 1.05 | 1.31 | 1.17 | 1.57 | 0.92 | 1.22 |
| 25 | 1.94 | 1.72 | 1.43 | 1.70 | 1.65 | 1.41 | 1.25 | 1.43 | 1.29 | 1.71 | 1.13 | 1.37 |
| 28 | 2.18 | 1.92 | 1.53 | 1.88 | 1.85 | 1.52 | 1.35 | 1.57 | 1.36 | 1.98 | 1.22 | 1.52 |
| 31 | 2.42 | 2.12 | 1.63 | 2.06 | 2.38 | 1.83 | 1.45 | 1.88 | 1.73 | 2.21 | 1.32 | 1.75 |
| | LD--40(T1) | | | | HD--40(T1) | | | | S-60(T1) | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 1.38 | 0.99 | 1.29 | 1.22 | 1.11 | 1.12 | 0.80 | 1.01 | 0.52 | 0.39 | 0.42 | 0.44 |
| 7 | 2.12 | 1.59 | 1.90 | 1.87 | 1.64 | 1.52 | 1.14 | 1.43 | 0.73 | 0.73 | 0.68 | 0.71 |
| 10 | 2.47 | 2.15 | 2.31 | 2.31 | 2.16 | 2.00 | 1.59 | 1.92 | 1.45 | 1.44 | 1.39 | 1.43 |
| 13 | 3.15 | 2.71 | 2.75 | 2.87 | 2.64 | 2.36 | 2.03 | 2.34 | 1.78 | 1.92 | 1.83 | 1.84 |
| 16 | 4.03 | 3.27 | 3.94 | 3.75 | 3.29 | 2.98 | 2.69 | 2.99 | 2.30 | 2.55 | 2.59 | 2.48 |
| 19 | 5.17 | 4.23 | 5.15 | 4.85 | 4.39 | 3.79 | 3.39 | 3.86 | 3.11 | 3.46 | 3.51 | 3.36 |
| 22 | 6.06 | 5.03 | 5.81 | 5.63 | 5.29 | 4.46 | 4.07 | 4.61 | 3.73 | 4.19 | 4.19 | 4.04 |
| 25 | 6.62 | 5.53 | 6.37 | 6.17 | 5.67 | 4.77 | 4.64 | 5.03 | 4.05 | 4.47 | 4.76 | 4.43 |
| 28 | 7.05 | 5.86 | 6.84 | 6.59 | 6.26 | 5.49 | 5.12 | 5.62 | 4.32 | 4.78 | 5.24 | 4.78 |
| 31 | 7.99 | 6.61 | 7.22 | 7.27 | 6.83 | 6.19 | 5.50 | 6.17 | 5.52 | 6.00 | 5.62 | 5.72 |
| | LD--60(T0) | | | | HD--60(T0) | | | | Non-wrapped (T) | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 4 | 0.32 | 0.15 | 0.20 | 0.22 | 0.21 | 0.13 | 0.16 | 0.17 | 1.88 | 1.94 | 1.91 | 1.91 |
| 7 | 0.60 | 0.35 | 0.53 | 0.50 | 0.36 | 0.32 | 0.23 | 0.31 | 3.44 | 3.82 | 3.62 | 3.63 |
| 10 | 0.67 | 0.52 | 0.69 | 0.62 | 0.41 | 0.46 | 0.36 | 0.41 | 5.13 | 5.79 | 6.05 | 5.65 |
| 13 | 0.87 | 0.67 | 0.84 | 0.79 | 0.46 | 0.62 | 0.53 | 0.54 | 7.65 | 8.60 | 8.36 | 8.20 |
| 16 | 1.09 | 0.92 | 1.12 | 1.04 | 0.91 | 0.78 | 0.71 | 0.80 | 8.99 | 9.33 | 9.10 | 9.14 |
| 19 | 1.30 | 1.19 | 1.40 | 1.30 | 1.18 | 0.99 | 0.83 | 1.00 | 11.30 | 15.32 | 11.64 | 12.75 |
| 22 | 1.48 | 1.36 | 1.60 | 1.48 | 1.36 | 1.12 | 1.03 | 1.17 | 13.91 | 22.28 | 14.11 | 16.77 |
| 25 | 1.59 | 1.49 | 1.80 | 1.63 | 1.53 | 1.23 | 1.23 | 1.33 | | | | |
| 28 | 1.64 | 1.54 | 1.89 | 1.69 | 1.63 | 1.32 | 1.33 | 1.42 | | | | |
| 31 | 2.10 | 1.86 | 2.00 | 1.99 | 2.03 | 1.69 | 1.43 | 1.71 | | | | |

| t | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | |
|----|-------------------|------|------|------|-------------------|------|------|------|----|----|----|------|--|
| | LD--60(T1) | | | | HD--60(T1) | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 1.01 | 1.17 | 1.01 | 1.06 | 0.96 | 0.96 | 0.77 | 0.90 | | | | | |
| 7 | 1.63 | 1.76 | 1.67 | 1.69 | 1.38 | 1.47 | 1.22 | 1.36 | | | | | |
| 10 | 1.94 | 2.05 | 1.90 | 1.96 | 1.56 | 1.89 | 1.29 | 1.58 | | | | | |
| 13 | 2.57 | 2.57 | 2.34 | 2.49 | 2.11 | 2.33 | 1.70 | 2.05 | | | | | |
| 16 | 3.27 | 3.45 | 3.37 | 3.37 | 2.98 | 2.91 | 2.38 | 2.76 | | | | | |
| 19 | 4.44 | 4.53 | 4.29 | 4.42 | 3.75 | 3.77 | 3.15 | 3.55 | | | | | |
| 22 | 5.30 | 5.37 | 4.96 | 5.21 | 4.33 | 4.38 | 3.83 | 4.18 | | | | | |
| 25 | 6.05 | 5.91 | 5.53 | 5.83 | 4.71 | 4.82 | 4.40 | 4.64 | | | | | |
| 28 | 6.71 | 6.59 | 6.01 | 6.44 | 5.11 | 5.29 | 4.88 | 5.09 | | | | | |
| 31 | 7.27 | 7.28 | 6.38 | 6.98 | 5.52 | 5.77 | 5.26 | 5.51 | | | | | |
| | LD--80(T0) | | | | HD--80(T0) | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 0.19 | 0.16 | 0.14 | 0.16 | 0.14 | 0.12 | 0.25 | 0.17 | | | | | |
| 7 | 0.44 | 0.39 | 0.37 | 0.40 | 0.35 | 0.24 | 0.35 | 0.31 | | | | | |
| 10 | 0.61 | 0.50 | 0.46 | 0.52 | 0.43 | 0.36 | 0.48 | 0.42 | | | | | |
| 13 | 0.71 | 0.64 | 0.60 | 0.65 | 0.52 | 0.50 | 0.61 | 0.54 | | | | | |
| 16 | 0.85 | 0.75 | 0.73 | 0.78 | 0.66 | 0.77 | 0.87 | 0.77 | | | | | |
| 19 | 1.09 | 1.03 | 0.91 | 1.01 | 0.76 | 0.93 | 1.03 | 0.91 | | | | | |
| 22 | 1.34 | 1.28 | 1.11 | 1.24 | 0.84 | 1.12 | 1.23 | 1.06 | | | | | |
| 25 | 1.48 | 1.37 | 1.30 | 1.39 | 0.94 | 1.41 | 1.52 | 1.29 | | | | | |
| 28 | 1.42 | 1.66 | 1.40 | 1.49 | 1.10 | 1.53 | 1.62 | 1.42 | | | | | |
| 31 | 1.97 | 1.98 | 1.50 | 1.82 | 1.23 | 1.88 | 1.96 | 1.69 | | | | | |
| | LD--80(T1) | | | | HD--80(T1) | | | | | | | | |
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | | | | |
| 4 | 0.94 | 0.74 | 1.09 | 0.92 | 0.92 | 0.84 | 0.82 | 0.86 | | | | | |
| 7 | 1.46 | 1.37 | 1.75 | 1.53 | 1.37 | 1.22 | 1.22 | 1.27 | | | | | |
| 10 | 1.73 | 1.69 | 2.16 | 1.86 | 1.70 | 1.36 | 1.41 | 1.49 | | | | | |
| 13 | 2.37 | 2.12 | 2.57 | 2.35 | 2.13 | 1.53 | 1.80 | 1.82 | | | | | |
| 16 | 3.18 | 2.97 | 3.83 | 3.33 | 2.80 | 2.45 | 2.38 | 2.54 | | | | | |
| 19 | 3.88 | 3.66 | 4.88 | 4.14 | 3.49 | 3.15 | 3.09 | 3.25 | | | | | |
| 22 | 4.59 | 4.28 | 5.55 | 4.80 | 4.11 | 3.80 | 3.77 | 3.89 | | | | | |
| 25 | 5.06 | 4.76 | 6.11 | 5.31 | 4.48 | 4.10 | 4.35 | 4.31 | | | | | |
| 28 | 5.64 | 4.54 | 8.02 | 6.07 | 5.20 | 4.70 | 4.82 | 4.91 | | | | | |
| 31 | 6.24 | 5.93 | 6.96 | 6.37 | 5.86 | 5.28 | 5.21 | 5.45 | | | | | |

APPENDIX - B

Table B1 Firmness under room temperature storage conditions

| Storage Period, t | Treatment replications | | | | | | | | | | | |
|-------------------|------------------------|-------|-------|-------|------------------|-------|-------|-------|------------------------|-------|-------|-------|
| | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. |
| | LD-40(T0) | | | | HD-40(T0) | | | | S-60(T0) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 7 | 12.95 | 12.90 | 12.95 | 12.93 | 13.00 | 13.00 | 13.00 | 13.00 | 11.20 | 11.10 | 11.50 | 11.27 |
| 10 | 5.70 | 5.60 | 6.60 | 5.97 | 7.80 | 7.40 | 7.95 | 7.72 | 4.20 | 4.10 | 5.10 | 4.47 |
| 13 | 5.00 | 4.90 | 5.10 | 5.00 | 6.00 | 5.10 | 5.90 | 5.67 | 4.10 | 4.10 | 4.80 | 4.33 |
| 16 | 4.50 | 4.30 | 5.10 | 4.63 | 4.90 | 5.10 | 5.40 | 5.13 | 4.00 | 4.00 | 4.40 | 4.13 |
| 19 | 3.50 | 3.20 | 4.00 | 3.57 | 4.00 | 4.20 | 4.40 | 4.20 | 3.80 | 3.90 | 4.40 | 4.03 |
| 22 | 3.50 | 3.60 | 3.30 | 3.47 | 4.10 | 3.90 | 4.10 | 4.03 | 3.60 | 3.80 | 4.00 | 3.80 |
| | LD-40(T1) | | | | HD-40(T1) | | | | S-60(T1) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 12.30 | 12.90 | 12.90 | 12.70 |
| 7 | 13.00 | 13.00 | 13.00 | 13.00 | 8.20 | 12.90 | 12.90 | 11.33 | 6.80 | 8.90 | 9.50 | 8.40 |
| 10 | 5.20 | 5.30 | 6.20 | 5.57 | 4.70 | 5.60 | 6.40 | 5.57 | 3.50 | 3.00 | 4.20 | 3.57 |
| 13 | 4.80 | 4.50 | 5.20 | 4.83 | 4.50 | 5.40 | 5.40 | 5.10 | 3.10 | 3.40 | 3.50 | 3.33 |
| 16 | 4.10 | 3.80 | 4.60 | 4.17 | 4.90 | 4.70 | 5.60 | 5.07 | 2.60 | 2.50 | 2.90 | 2.67 |
| 19 | 3.10 | 3.00 | 3.60 | 3.23 | 3.90 | 4.10 | 5.10 | 4.37 | | | | |
| 22 | 3.20 | 3.20 | 2.80 | 3.07 | 3.80 | 3.90 | 4.20 | 3.97 | | | | |
| | LD-40(T2) | | | | HD-40(T2) | | | | S-60(T2) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 7 | 9.90 | 5.00 | 9.90 | 8.27 | 12.60 | 12.50 | 12.90 | 12.67 | 4.50 | 6.90 | 7.50 | 6.30 |
| 10 | 5.20 | 4.60 | 5.50 | 5.10 | 4.80 | 5.10 | 5.10 | 5.00 | 4.40 | 4.30 | 4.50 | 4.40 |
| 13 | 4.10 | 4.40 | 5.10 | 4.53 | 4.50 | 4.50 | 4.60 | 4.53 | 3.50 | 3.40 | 3.50 | 3.47 |
| 16 | 3.60 | 4.20 | 5.10 | 4.30 | 3.80 | 4.20 | 3.70 | 3.90 | 3.30 | 3.10 | 3.10 | 3.17 |
| 19 | 3.20 | 3.90 | 4.00 | 3.70 | 3.80 | 3.70 | 3.90 | 3.80 | | | | |
| 22 | 3.10 | 3.10 | 3.90 | 3.37 | 3.30 | 3.60 | 3.50 | 3.47 | | | | |
| | LD-40(T3) | | | | HD-40(T3) | | | | S-60(T3) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 11.30 | 12.90 | 12.90 | 12.37 |
| 7 | 4.80 | 5.80 | 8.10 | 6.23 | 9.80 | 9.70 | 10.20 | 9.90 | 8.80 | 10.00 | 10.00 | 9.60 |
| 10 | 4.80 | 4.50 | 5.60 | 4.97 | 6.80 | 6.80 | 6.90 | 6.83 | 7.20 | 7.10 | 7.20 | 7.17 |
| 13 | 4.50 | 4.40 | 5.50 | 4.80 | 4.40 | 4.20 | 4.60 | 4.40 | 3.30 | 3.30 | 3.30 | 3.30 |
| 16 | 3.90 | 4.30 | 5.40 | 4.53 | 4.30 | 4.20 | 4.50 | 4.33 | 3.00 | 2.90 | 3.00 | 2.97 |
| 19 | 3.20 | 3.90 | 4.90 | 4.00 | 3.60 | 3.60 | 3.70 | 3.63 | | | | |
| 22 | 2.90 | 2.90 | 3.10 | 2.97 | 3.40 | 3.30 | 3.50 | 3.40 | | | | |
| | LD-60(T0) | | | | HD-60(T0) | | | | Non-wrapped (T) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 10.00 | 11.60 | 11.10 | 10.90 |
| 7 | 12.00 | 12.95 | 12.95 | 12.63 | 12.60 | 12.90 | 12.95 | 12.82 | 8.00 | 9.70 | 8.00 | 8.57 |
| 10 | 7.00 | 10.20 | 11.50 | 9.57 | 8.00 | 11.60 | 11.75 | 10.45 | 4.70 | 5.40 | 4.70 | 4.93 |
| 13 | 5.50 | 4.60 | 7.00 | 5.70 | 4.80 | 4.70 | 4.90 | 4.80 | | | | |
| 16 | 5.40 | 4.70 | 5.20 | 5.10 | 3.90 | 3.90 | 4.80 | 4.20 | | | | |
| 19 | 4.70 | 4.20 | 5.10 | 4.67 | 3.80 | 3.40 | 3.90 | 3.70 | | | | |
| 22 | 4.30 | 3.80 | 5.10 | 4.40 | 3.70 | 3.30 | 3.80 | 3.60 | | | | |
| 25 | 4.20 | 3.90 | 4.25 | 4.12 | | | | | | | | |
| | LD-60(T1) | | | | HD-60(T1) | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 11.80 | 12.85 | 12.95 | 12.53 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 5.20 | 5.20 | 6.10 | 5.50 | 9.40 | 12.95 | 12.90 | 11.75 | | | | |
| 10 | 5.20 | 5.20 | 5.70 | 5.37 | 4.10 | 4.70 | 4.80 | 4.53 | | | | |
| 13 | 5.10 | 5.10 | 5.60 | 5.27 | 3.90 | 4.20 | 4.70 | 4.27 | | | | |
| 16 | 5.00 | 5.00 | 5.10 | 5.03 | 3.90 | 4.00 | 4.40 | 4.10 | | | | |
| 19 | 4.40 | 4.80 | 5.00 | 4.73 | 3.40 | 3.40 | 3.40 | 3.40 | | | | |
| 22 | 4.00 | 4.10 | 3.90 | 4.00 | 3.30 | 3.20 | 3.30 | 3.27 | | | | |
| 25 | 3.30 | 3.70 | 3.70 | 3.57 | | | | | | | | |

| t | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. |
|------------------|-------|-------|-------|-------|-------|-------|-------|-------|----|----|----|------|
| LD-80(T2) | | | | | | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 12.90 | 12.90 | 12.90 | 12.90 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 5.90 | 6.90 | 7.80 | 6.87 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 10 | 5.80 | 4.80 | 6.20 | 5.60 | 5.60 | 5.10 | 5.90 | 5.53 | | | | |
| 13 | 5.00 | 4.70 | 5.70 | 5.13 | 4.40 | 4.95 | 5.20 | 4.85 | | | | |
| 16 | 3.90 | 4.60 | 5.00 | 4.50 | 4.25 | 4.30 | 5.10 | 4.55 | | | | |
| 19 | 3.90 | 3.90 | 4.30 | 4.03 | 4.20 | 4.00 | 4.20 | 4.13 | | | | |
| 22 | 3.50 | 3.50 | 3.60 | 3.53 | 3.50 | 3.30 | 3.70 | 3.50 | | | | |
| 25 | 3.10 | 3.00 | 3.60 | 3.23 | | | | | | | | |
| LD-80(T3) | | | | | | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 6.10 | 7.60 | 7.70 | 7.13 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 10 | 5.80 | 6.20 | 6.50 | 6.17 | 3.80 | 4.60 | 5.50 | 4.63 | | | | |
| 13 | 5.60 | 6.00 | 6.40 | 6.00 | 3.80 | 3.80 | 3.80 | 3.80 | | | | |
| 16 | 4.30 | 5.80 | 5.90 | 5.33 | 3.65 | 3.65 | 3.70 | 3.67 | | | | |
| 19 | 3.90 | 4.20 | 4.40 | 4.17 | 3.60 | 3.40 | 3.70 | 3.57 | | | | |
| 22 | 3.20 | 3.10 | 3.10 | 3.13 | 3.60 | 3.30 | 3.60 | 3.50 | | | | |
| LD-80(T0) | | | | | | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 11.60 | 12.80 | 12.90 | 12.43 | 11.20 | 11.00 | 11.00 | 11.07 | | | | |
| 10 | 10.10 | 10.50 | 11.90 | 10.83 | 5.10 | 6.50 | 6.60 | 6.07 | | | | |
| 13 | 9.00 | 9.20 | 11.70 | 9.97 | 4.60 | 5.60 | 6.60 | 5.60 | | | | |
| 16 | 7.70 | 8.50 | 9.30 | 8.50 | 4.50 | 5.10 | 6.10 | 5.23 | | | | |
| 19 | 4.80 | 8.00 | 9.00 | 7.27 | 4.90 | 4.70 | 5.30 | 4.97 | | | | |
| 22 | 4.70 | 5.70 | 8.40 | 6.27 | 4.00 | 4.50 | 5.30 | 4.60 | | | | |
| 25 | 4.50 | 4.70 | 5.30 | 4.83 | 3.70 | 3.80 | 5.20 | 4.23 | | | | |
| 28 | 4.40 | 4.60 | 4.80 | 4.60 | | | | | | | | |
| LD-80(T1) | | | | | | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 12.90 | 12.80 | 12.95 | 12.88 | 10.00 | 10.20 | 10.70 | 10.30 | | | | |
| 10 | 4.70 | 6.30 | 5.10 | 5.37 | 4.80 | 5.50 | 5.80 | 5.37 | | | | |
| 13 | 4.50 | 4.60 | 4.70 | 4.60 | 4.70 | 4.30 | 5.80 | 4.93 | | | | |
| 16 | 4.10 | 4.10 | 4.50 | 4.23 | 4.30 | 4.30 | 4.60 | 4.40 | | | | |
| 19 | 3.90 | 3.60 | 4.50 | 4.00 | 3.80 | 4.10 | 4.40 | 4.10 | | | | |
| 22 | 3.60 | 3.40 | 3.20 | 3.40 | 3.70 | 3.80 | 4.20 | 3.90 | | | | |
| 25 | 3.60 | 3.40 | 2.90 | 3.30 | | | | | | | | |
| LD-80(T2) | | | | | | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 13.00 | 13.00 | 13.00 | 13.00 | 9.95 | 10.00 | 10.00 | 9.98 | | | | |
| 10 | 5.20 | 4.60 | 4.90 | 4.90 | 6.20 | 6.60 | 5.90 | 6.23 | | | | |
| 13 | 5.00 | 4.40 | 4.60 | 4.67 | 5.20 | 6.20 | 5.30 | 5.57 | | | | |
| 16 | 4.50 | 4.20 | 4.50 | 4.40 | 4.70 | 4.40 | 5.60 | 4.90 | | | | |
| 19 | 4.20 | 3.90 | 4.50 | 4.20 | 4.30 | 4.20 | 4.40 | 4.30 | | | | |
| 22 | 3.50 | 3.80 | 3.80 | 3.70 | 4.20 | 3.80 | 4.40 | 4.13 | | | | |
| 25 | 3.00 | 3.10 | 3.10 | 3.07 | | | | | | | | |
| LD-80(T3) | | | | | | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 12.95 | 12.90 | 12.50 | 12.78 | 9.50 | 9.90 | 9.90 | 9.77 | | | | |
| 10 | 4.30 | 5.50 | 6.10 | 5.30 | 4.90 | 5.20 | 7.80 | 5.97 | | | | |
| 13 | 4.20 | 4.60 | 6.10 | 4.97 | 3.80 | 4.20 | 5.40 | 4.47 | | | | |
| 16 | 4.20 | 4.40 | 4.60 | 4.40 | 3.70 | 4.00 | 4.10 | 3.93 | | | | |
| 19 | 3.70 | 3.60 | 3.90 | 3.73 | 3.70 | 3.70 | 3.90 | 3.77 | | | | |
| 22 | 2.90 | 3.60 | 3.00 | 3.17 | 3.50 | 3.80 | 3.70 | 3.67 | | | | |

Table B2 Firmness under brick & sand storage conditions

| Storage Period.t | Treatment replications | | | | | | | | | | | |
|------------------|------------------------|-------|-------|-------|------------------|-------|-------|-------|------------------------|-------|-------|-------|
| | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. |
| | LD-40(T0) | | | | HD-40(T0) | | | | S-60(T0) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 7 | 7.70 | 6.10 | 9.40 | 7.73 | 12.90 | 11.00 | 13.90 | 12.60 | 9.70 | 10.20 | 11.50 | 10.47 |
| 10 | 5.60 | 5.80 | 6.50 | 5.97 | 6.30 | 5.60 | 6.40 | 6.10 | 5.60 | 6.00 | 7.00 | 6.20 |
| 13 | 4.60 | 5.60 | 6.00 | 5.40 | 5.20 | 5.10 | 5.70 | 5.33 | 5.40 | 5.60 | 6.00 | 5.67 |
| 16 | 4.60 | 4.70 | 5.80 | 5.03 | 4.80 | 5.10 | 5.50 | 5.13 | 5.20 | 5.20 | 5.50 | 5.30 |
| 19 | 4.50 | 4.70 | 5.60 | 4.93 | 4.30 | 4.70 | 5.40 | 4.80 | 4.80 | 4.80 | 5.30 | 4.97 |
| 22 | 4.10 | 4.00 | 5.30 | 4.47 | 4.20 | 4.10 | 5.20 | 4.50 | 4.60 | 4.10 | 5.10 | 4.60 |
| 25 | 4.00 | 4.00 | 4.30 | 4.10 | | | | | 4.20 | 4.10 | 4.63 | 4.31 |
| | LD-40(T1) | | | | HD-40(T1) | | | | S-60(T1) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 11.50 | 12.95 | 12.95 | 12.47 |
| 7 | 8.50 | 10.90 | 10.90 | 10.10 | 12.85 | 6.90 | 12.80 | 10.85 | 7.60 | 9.00 | 10.70 | 9.10 |
| 10 | 5.70 | 5.70 | 5.80 | 5.73 | 6.10 | 6.20 | 7.20 | 6.50 | 6.30 | 6.30 | 6.30 | 6.30 |
| 13 | 5.10 | 4.90 | 5.10 | 5.03 | 5.60 | 5.30 | 6.40 | 5.77 | 5.70 | 5.80 | 5.80 | 5.77 |
| 16 | 4.30 | 4.20 | 4.50 | 4.33 | 4.50 | 5.00 | 5.70 | 5.07 | 4.50 | 4.70 | 4.70 | 4.63 |
| 19 | 4.30 | 4.00 | 4.30 | 4.20 | 4.50 | 4.80 | 4.80 | 4.70 | 4.40 | 4.60 | 4.60 | 4.53 |
| 22 | 4.20 | 3.90 | 4.00 | 4.03 | 4.30 | 4.20 | 4.50 | 4.33 | 4.40 | 4.10 | 4.20 | 4.23 |
| | LD-40(T2) | | | | HD-40(T2) | | | | S-60(T2) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 7 | 7.40 | 12.80 | 12.75 | 10.98 | 6.20 | 8.80 | 9.70 | 8.23 | 7.10 | 13.00 | 13.00 | 11.03 |
| 10 | 7.00 | 5.00 | 8.20 | 6.73 | 5.60 | 5.30 | 6.80 | 5.90 | 5.40 | 5.50 | 5.90 | 5.60 |
| 13 | 4.60 | 4.90 | 5.90 | 5.20 | 5.50 | 4.50 | 5.70 | 5.23 | 5.10 | 5.10 | 5.60 | 5.27 |
| 16 | 4.60 | 4.80 | 5.10 | 4.83 | 4.30 | 4.10 | 4.90 | 4.43 | 4.40 | 4.90 | 5.10 | 4.80 |
| 19 | 3.70 | 4.40 | 4.80 | 4.30 | 4.00 | 4.10 | 4.40 | 4.17 | 4.20 | 4.40 | 4.60 | 4.40 |
| 22 | 3.90 | 3.70 | 4.20 | 3.93 | 3.80 | 3.90 | 4.20 | 3.97 | 4.20 | 4.30 | 4.50 | 4.33 |
| | LD-40(T3) | | | | HD-40(T3) | | | | S-60(T3) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 7 | 5.60 | 7.70 | 8.40 | 7.23 | 13.00 | 13.00 | 13.00 | 13.00 | 10.20 | 12.80 | 12.85 | 11.95 |
| 10 | 5.30 | 5.20 | 5.20 | 5.23 | 4.80 | 6.30 | 7.20 | 6.10 | 5.00 | 5.00 | 5.20 | 5.07 |
| 13 | 4.40 | 4.80 | 5.20 | 4.80 | 4.60 | 5.20 | 5.30 | 5.03 | 5.00 | 4.80 | 5.10 | 4.97 |
| 16 | 4.20 | 4.60 | 5.10 | 4.63 | 4.40 | 4.80 | 4.80 | 4.67 | 4.60 | 4.80 | 5.10 | 4.83 |
| 19 | 4.10 | 4.20 | 4.30 | 4.20 | 3.60 | 3.60 | 3.70 | 3.63 | 4.50 | 4.50 | 5.00 | 4.67 |
| 22 | 3.90 | 4.10 | 4.00 | 4.00 | 3.60 | 3.30 | 3.70 | 3.53 | 4.00 | 4.50 | 4.60 | 4.37 |
| | LD-60(T0) | | | | HD-60(T0) | | | | Non-wrapped (T) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 7 | 7.50 | 9.40 | 9.60 | 8.83 | 8.10 | 7.60 | 8.50 | 8.07 | 9.10 | 9.50 | 12.70 | 10.43 |
| 10 | 7.20 | 7.20 | 9.00 | 7.80 | 6.40 | 6.40 | 6.80 | 6.53 | 5.20 | 5.00 | 5.50 | 5.23 |
| 13 | 7.00 | 6.70 | 7.40 | 7.03 | 5.60 | 5.60 | 5.80 | 5.67 | | | | |
| 16 | 5.90 | 5.90 | 6.50 | 6.10 | 5.00 | 5.00 | 5.60 | 5.20 | | | | |
| 19 | 4.70 | 5.60 | 6.30 | 5.53 | 4.20 | 4.40 | 4.30 | 4.30 | | | | |
| 22 | 4.60 | 4.60 | 5.90 | 5.03 | 3.50 | 3.80 | 3.90 | 3.73 | | | | |
| 25 | 4.90 | 4.80 | 4.80 | 4.83 | | | | | | | | |
| 28 | 4.20 | 4.30 | 3.90 | 4.13 | | | | | | | | |
| | LD-60(T1) | | | | HD-60(T1) | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 9.90 | 12.95 | 12.95 | 11.93 | | | | |
| 7 | 9.10 | 6.50 | 9.70 | 8.43 | 8.60 | 5.90 | 10.50 | 8.33 | | | | |
| 10 | 5.90 | 6.10 | 6.50 | 6.17 | 4.80 | 4.70 | 6.60 | 5.37 | | | | |
| 13 | 5.20 | 6.00 | 6.10 | 5.77 | 4.80 | 4.60 | 6.00 | 5.13 | | | | |
| 16 | 5.00 | 5.50 | 5.90 | 5.47 | 4.70 | 3.90 | 5.10 | 4.57 | | | | |
| 19 | 5.00 | 5.20 | 5.60 | 5.27 | 4.00 | 3.90 | 4.10 | 4.00 | | | | |
| 22 | 4.80 | 4.60 | 5.30 | 4.90 | 4.00 | 3.90 | 4.00 | 3.97 | | | | |
| 25 | 4.40 | 4.30 | 3.90 | 4.20 | | | | | | | | |

| t | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. |
|----|------------------|-------|-------|-------|------------------|-------|-------|-------|----|----|----|------|
| | LD-80(T2) | | | | HD-80(T2) | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 11.20 | 13.00 | 13.00 | 12.40 | | | | |
| 7 | 6.30 | 7.00 | 8.10 | 7.13 | 8.50 | 7.30 | 8.80 | 8.20 | | | | |
| 10 | 6.30 | 6.30 | 7.30 | 6.63 | 6.20 | 6.90 | 7.50 | 6.87 | | | | |
| 13 | 6.20 | 6.20 | 6.90 | 6.43 | 4.60 | 5.60 | 6.40 | 5.53 | | | | |
| 16 | 5.40 | 5.70 | 6.40 | 5.83 | 4.60 | 4.30 | 5.20 | 4.70 | | | | |
| 19 | 5.30 | 5.30 | 6.30 | 5.63 | 4.20 | 3.80 | 4.60 | 4.20 | | | | |
| 22 | 4.90 | 5.10 | 4.80 | 4.93 | 3.70 | 3.80 | 3.90 | 3.80 | | | | |
| 25 | 4.90 | 4.10 | 4.30 | 4.43 | | | | | | | | |
| | LD-80(T3) | | | | HD-80(T3) | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 12.20 | 13.00 | 13.00 | 12.73 | | | | |
| 7 | 7.40 | 6.70 | 7.70 | 7.27 | 7.50 | 5.30 | 9.80 | 7.53 | | | | |
| 10 | 7.00 | 6.60 | 7.00 | 6.87 | 5.20 | 5.10 | 5.20 | 5.17 | | | | |
| 13 | 5.20 | 5.70 | 6.80 | 5.90 | 4.90 | 4.40 | 5.20 | 4.83 | | | | |
| 16 | 5.20 | 5.30 | 5.60 | 5.37 | 4.50 | 4.40 | 4.90 | 4.60 | | | | |
| 19 | 4.90 | 5.00 | 5.30 | 5.07 | 4.50 | 4.00 | 4.60 | 4.37 | | | | |
| 22 | 4.50 | 4.50 | 5.00 | 4.67 | 3.30 | 3.10 | 3.80 | 3.40 | | | | |
| | LD-80(T0) | | | | HD-80(T0) | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 9.50 | 12.90 | 12.90 | 11.77 | 7.60 | 12.80 | 12.95 | 11.12 | | | | |
| 10 | 8.40 | 12.90 | 12.90 | 11.40 | 6.30 | 7.00 | 8.00 | 7.10 | | | | |
| 13 | 8.30 | 9.90 | 8.20 | 8.80 | 5.60 | 5.90 | 6.50 | 6.00 | | | | |
| 16 | 7.20 | 6.70 | 6.80 | 6.90 | 5.20 | 4.80 | 6.40 | 5.47 | | | | |
| 19 | 7.20 | 5.30 | 6.10 | 6.20 | 4.80 | 4.50 | 5.60 | 4.97 | | | | |
| 22 | 6.50 | 5.00 | 5.00 | 5.50 | 4.00 | 3.90 | 4.80 | 4.23 | | | | |
| 25 | 5.70 | 4.80 | 4.20 | 4.90 | 3.70 | 3.60 | 4.00 | 3.77 | | | | |
| 28 | 5.20 | 3.70 | 3.60 | 4.17 | | | | | | | | |
| | LD-80(T1) | | | | HD-80(T1) | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 7 | 11.80 | 10.20 | 12.00 | 11.33 | 7.40 | 10.10 | 11.30 | 9.60 | | | | |
| 10 | 5.30 | 5.30 | 5.70 | 5.43 | 6.40 | 6.50 | 7.70 | 6.87 | | | | |
| 13 | 5.30 | 5.00 | 5.70 | 5.33 | 5.00 | 4.80 | 5.20 | 5.00 | | | | |
| 16 | 4.90 | 4.70 | 5.20 | 4.93 | 5.00 | 4.50 | 5.00 | 4.83 | | | | |
| 19 | 4.90 | 4.70 | 5.00 | 4.87 | 3.90 | 3.90 | 4.10 | 3.97 | | | | |
| 22 | 4.00 | 3.80 | 4.10 | 3.97 | 3.70 | 3.70 | 4.00 | 3.80 | | | | |
| 25 | 3.10 | 3.00 | 3.20 | 3.10 | | | | | | | | |
| | LD-80(T2) | | | | HD-80(T2) | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 8.30 | 12.95 | 12.95 | 11.40 | | | | |
| 7 | 8.50 | 7.80 | 10.20 | 8.83 | 7.20 | 12.50 | 12.80 | 10.83 | | | | |
| 10 | 5.80 | 7.00 | 7.90 | 6.90 | 6.10 | 6.60 | 7.40 | 6.70 | | | | |
| 13 | 5.70 | 6.90 | 7.00 | 6.53 | 4.70 | 4.40 | 4.80 | 4.63 | | | | |
| 16 | 5.40 | 5.00 | 6.10 | 5.50 | 4.40 | 4.30 | 4.60 | 4.43 | | | | |
| 19 | 4.80 | 4.80 | 5.50 | 5.03 | 4.40 | 4.00 | 4.50 | 4.30 | | | | |
| 22 | 3.80 | 4.70 | 4.90 | 4.47 | 3.80 | 3.80 | 3.90 | 3.83 | | | | |
| 25 | 3.80 | 4.10 | 4.20 | 4.03 | | | | | | | | |
| | LD-80(T3) | | | | HD-80(T3) | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 12.30 | 12.95 | 12.95 | 12.73 | | | | |
| 7 | 8.80 | 8.90 | 12.20 | 9.97 | 10.30 | 11.90 | 12.90 | 11.70 | | | | |
| 10 | 7.30 | 8.20 | 8.70 | 8.07 | 8.00 | 5.50 | 10.30 | 7.93 | | | | |
| 13 | 6.10 | 5.90 | 7.00 | 6.33 | 5.20 | 5.10 | 6.40 | 5.57 | | | | |
| 16 | 5.50 | 5.60 | 6.50 | 5.87 | 4.20 | 5.00 | 5.80 | 5.00 | | | | |
| 19 | 5.30 | 5.30 | 6.50 | 5.70 | 4.00 | 4.60 | 5.20 | 4.60 | | | | |
| 22 | 5.20 | 5.00 | 6.40 | 5.53 | 3.50 | 3.50 | 3.70 | 3.57 | | | | |

Table B3 Firmness under cold storage conditions

| Storage Period,t | Treatment replications | | | | | | | | | | | |
|------------------|------------------------|-------|-------|-------|------------------|-------|-------|-------|------------------------|-------|-------|-------|
| | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. |
| | LD-40(T0) | | | | HD-40(T0) | | | | S-60(T0) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 8 | 10.80 | 11.50 | 11.20 | 11.17 | 10.70 | 11.20 | 11.00 | 10.97 | 12.00 | 12.20 | 12.10 | 12.10 |
| 15 | 8.70 | 10.10 | 9.50 | 9.43 | 8.50 | 9.60 | 9.10 | 9.07 | 11.40 | 11.80 | 11.70 | 11.63 |
| 22 | 8.70 | 8.50 | 8.60 | 8.60 | 8.50 | 8.10 | 8.20 | 8.27 | 8.80 | 8.40 | 8.50 | 8.57 |
| 31 | 5.00 | 5.20 | 7.50 | 5.90 | 5.50 | 6.20 | 3.80 | 5.17 | 6.40 | 6.00 | 5.90 | 6.10 |
| | LD-40(T1) | | | | HD-40(T1) | | | | S-60(T1) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 8 | 12.60 | 13.00 | 12.20 | 12.60 | 11.70 | 11.50 | 11.50 | 11.57 | 13.00 | 13.00 | 12.70 | 12.90 |
| 15 | 12.30 | 12.10 | 12.50 | 12.30 | 10.40 | 10.30 | 10.50 | 10.40 | 12.90 | 12.90 | 12.60 | 12.80 |
| 22 | 9.50 | 9.10 | 9.30 | 9.30 | 7.30 | 6.90 | 7.20 | 7.13 | 10.50 | 10.10 | 10.00 | 10.20 |
| 31 | 7.20 | 6.00 | 5.00 | 6.07 | 5.80 | 5.80 | 5.90 | 5.83 | 5.10 | 5.60 | 5.60 | 5.43 |
| | LD-60(T0) | | | | HD-60(T0) | | | | Non-wrapped (T) | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| 8 | 10.40 | 11.70 | 11.20 | 11.10 | 8.70 | 10.80 | 9.80 | 9.77 | 13.00 | 13.00 | 13.00 | 13.00 |
| 15 | 7.90 | 10.40 | 9.20 | 9.17 | 6.50 | 8.70 | 7.50 | 7.57 | 13.00 | 13.00 | 13.00 | 13.00 |
| 22 | 7.90 | 7.70 | 8.10 | 7.90 | 7.70 | 7.30 | 4.50 | 6.50 | 7.15 | 8.35 | 7.75 | 7.75 |
| 31 | 5.70 | 5.20 | 5.30 | 5.40 | 6.50 | 6.30 | 6.50 | 6.43 | | | | |
| | LD-60(T1) | | | | HD-60(T1) | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 8 | 10.90 | 11.30 | 11.40 | 11.20 | 11.55 | 10.65 | 11.10 | 11.10 | | | | |
| 15 | 8.90 | 9.70 | 9.30 | 9.30 | 10.10 | 8.50 | 9.30 | 9.30 | | | | |
| 22 | 8.50 | 8.30 | 8.70 | 8.50 | 8.50 | 8.40 | 8.40 | 8.43 | | | | |
| 31 | 5.40 | 6.30 | 5.70 | 5.80 | 5.90 | 8.50 | 4.60 | 6.33 | | | | |
| | LD-80(T0) | | | | HD-80(T0) | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 8 | 12.40 | 12.10 | 12.10 | 12.20 | 12.20 | 12.00 | 12.00 | 12.07 | | | | |
| 15 | 11.90 | 11.40 | 11.20 | 11.50 | 11.40 | 11.00 | 11.30 | 11.23 | | | | |
| 22 | 8.50 | 8.30 | 8.70 | 8.50 | 7.20 | 6.70 | 12.40 | 8.77 | | | | |
| 31 | 4.70 | 5.00 | 5.00 | 4.90 | 7.80 | 7.50 | 7.50 | 7.60 | | | | |
| | LD-80(T1) | | | | HD-80(T1) | | | | | | | |
| 1 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 | | | | |
| 8 | 12.10 | 13.00 | 12.40 | 12.50 | 11.60 | 12.30 | 12.00 | 11.97 | | | | |
| 15 | 11.40 | 12.90 | 11.70 | 12.00 | 10.20 | 11.50 | 11.00 | 10.90 | | | | |
| 22 | 9.10 | 8.80 | 8.50 | 8.80 | 10.20 | 9.90 | 10.10 | 10.07 | | | | |
| 31 | 7.40 | 5.60 | 6.10 | 6.37 | 6.20 | 5.50 | 5.90 | 5.87 | | | | |

APPENDIX - C

Table C1 Total soluble solids under room temperature storage conditions

| Storage Period, t | Treatment replications | | | | | | | | | | | |
|-------------------|------------------------|-------|-------|-------|------------------|-------|-------|-------|--------------------|-------|-------|-------|
| | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. |
| | LD-40(T0) | | | | HD-40(T0) | | | | S-60(T0) | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 |
| 4 | 10.80 | 11.00 | 10.90 | 10.90 | 9.50 | 9.20 | 9.80 | 9.50 | 10.80 | 10.70 | 10.90 | 10.80 |
| 7 | 15.00 | 14.50 | 14.90 | 14.80 | 12.10 | 12.20 | 12.30 | 12.20 | 14.00 | 14.30 | 13.70 | 14.00 |
| 10 | 14.80 | 16.40 | 15.60 | 15.60 | 16.00 | 17.00 | 16.50 | 16.50 | 15.00 | 14.50 | 14.90 | 14.80 |
| 13 | 16.20 | 17.50 | 17.00 | 16.90 | 16.80 | 16.70 | 16.90 | 16.80 | 18.00 | 17.80 | 18.20 | 18.00 |
| 16 | 15.00 | 13.20 | 14.00 | 14.07 | 16.60 | 16.40 | 16.50 | 16.50 | 12.80 | 14.50 | 13.80 | 13.70 |
| 19 | 12.90 | 13.50 | 13.20 | 13.20 | 11.90 | 12.40 | 12.30 | 12.20 | 12.60 | 13.00 | 12.80 | 12.80 |
| 22 | 12.50 | 12.30 | 12.70 | 12.50 | 12.00 | 11.80 | 11.60 | 11.80 | 12.40 | 12.70 | 12.70 | 12.60 |
| | LD-40(T1) | | | | HD-40(T1) | | | | S-60(T1) | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 |
| 4 | 11.40 | 11.50 | 11.60 | 11.50 | 9.50 | 9.40 | 9.60 | 9.50 | 11.00 | 10.90 | 11.10 | 11.00 |
| 7 | 19.40 | 19.20 | 19.60 | 19.40 | 10.00 | 15.90 | 13.10 | 13.00 | 15.90 | 17.20 | 16.70 | 16.60 |
| 10 | 19.00 | 16.00 | 17.50 | 17.50 | 16.50 | 16.10 | 16.30 | 16.30 | 19.00 | 18.60 | 19.40 | 19.00 |
| 13 | 15.80 | 15.80 | 15.80 | 15.80 | 16.00 | 18.90 | 17.60 | 17.50 | 16.00 | 15.80 | 16.20 | 16.00 |
| 16 | 14.00 | 14.60 | 14.30 | 14.30 | 12.60 | 13.00 | 12.80 | 12.80 | 15.00 | 16.00 | 15.50 | 15.50 |
| 19 | 10.50 | 11.00 | 10.90 | 10.80 | 10.60 | 13.00 | 11.80 | 11.80 | | | | |
| 22 | 10.50 | 10.70 | 10.00 | 10.40 | 11.50 | 11.70 | 11.30 | 11.50 | | | | |
| | LD-40(T2) | | | | HD-40(T2) | | | | S-60(T2) | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 |
| 4 | 11.50 | 11.80 | 11.80 | 11.70 | 9.40 | 9.70 | 9.10 | 9.40 | 8.00 | 8.20 | 8.10 | 8.10 |
| 7 | 11.50 | 13.90 | 12.70 | 12.70 | 10.90 | 11.00 | 11.10 | 11.00 | 15.90 | 17.00 | 16.60 | 16.50 |
| 10 | 16.00 | 16.00 | 20.50 | 17.50 | 17.00 | 17.00 | 17.00 | 17.00 | 21.00 | 20.90 | 21.10 | 21.00 |
| 13 | 10.80 | 11.00 | 28.60 | 16.80 | 16.10 | 15.00 | 15.70 | 15.60 | 17.60 | 15.90 | 19.30 | 17.60 |
| 16 | 19.00 | 16.00 | 13.00 | 16.00 | 14.00 | 14.00 | 17.00 | 15.00 | 16.50 | 17.40 | 17.10 | 17.00 |
| 19 | 14.70 | 15.10 | 14.90 | 14.90 | 17.60 | 15.00 | 9.40 | 14.00 | | | | |
| 22 | 14.50 | 14.70 | 14.00 | 14.40 | 13.30 | 13.50 | 13.70 | 13.50 | | | | |
| | LD-40(T3) | | | | HD-40(T3) | | | | S-60(T3) | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 |
| 4 | 8.90 | 9.00 | 8.80 | 8.90 | 9.00 | 8.90 | 9.10 | 9.00 | 12.80 | 13.00 | 12.90 | 12.90 |
| 7 | 11.00 | 12.00 | 11.50 | 11.50 | 9.40 | 9.50 | 9.30 | 9.40 | 16.00 | 16.00 | 16.00 | 16.00 |
| 10 | 16.00 | 14.00 | 15.00 | 15.00 | 18.00 | 20.00 | 19.00 | 19.00 | 17.40 | 17.10 | 17.70 | 17.40 |
| 13 | 18.30 | 17.00 | 17.80 | 17.70 | 15.00 | 13.50 | 15.90 | 14.80 | 17.00 | 16.70 | 17.30 | 17.00 |
| 16 | 15.00 | 16.50 | 15.90 | 15.80 | 14.80 | 13.70 | 14.40 | 14.30 | 16.00 | 15.90 | 16.10 | 16.00 |
| 19 | 12.60 | 13.00 | 12.80 | 12.80 | 14.50 | 13.10 | 13.80 | 13.80 | | | | |
| 22 | 12.20 | 12.50 | 12.50 | 12.40 | 13.50 | 13.80 | 13.50 | 13.60 | | | | |
| | LD-60(T0) | | | | HD-60(T0) | | | | Non-wrapped | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 |
| 4 | 12.50 | 11.50 | 12.00 | 12.00 | 9.60 | 9.50 | 9.70 | 9.60 | 11.00 | 11.30 | 11.90 | 11.40 |
| 7 | 16.00 | 16.00 | 16.00 | 16.00 | 11.00 | 13.00 | 12.00 | 12.00 | 15.50 | 16.00 | 15.90 | 15.80 |
| 10 | 16.00 | 17.00 | 16.50 | 16.50 | 17.00 | 18.40 | 17.70 | 17.70 | 16.00 | 17.50 | 16.90 | 16.80 |
| 13 | 18.10 | 17.90 | 18.30 | 18.10 | 18.50 | 18.40 | 18.60 | 18.50 | | | | |
| 16 | 15.80 | 15.90 | 15.70 | 15.80 | 17.00 | 17.40 | 17.20 | 17.20 | | | | |
| 19 | 14.60 | 14.50 | 14.50 | 14.53 | 17.30 | 15.90 | 16.60 | 16.60 | | | | |
| 22 | 12.80 | 12.60 | 13.00 | 12.80 | 15.00 | 15.30 | 15.30 | 15.20 | | | | |
| 25 | 12.40 | 12.50 | 12.60 | 12.50 | | | | | | | | |
| | LD-80(T1) | | | | HD-60(T1) | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | |
| 4 | 13.20 | 13.30 | 13.40 | 13.30 | 9.90 | 9.50 | 10.30 | 9.90 | | | | |
| 7 | 15.00 | 15.00 | 15.00 | 15.00 | 10.50 | 14.00 | 12.40 | 12.30 | | | | |
| 10 | 18.80 | 19.00 | 18.90 | 18.90 | 15.00 | 16.10 | 15.70 | 15.60 | | | | |
| 13 | 15.90 | 16.00 | 15.60 | 15.83 | 17.10 | 15.80 | 16.60 | 16.50 | | | | |
| 16 | 13.10 | 13.00 | 13.20 | 13.10 | 14.00 | 14.00 | 14.00 | 14.00 | | | | |
| 19 | 10.80 | 11.00 | 13.90 | 11.90 | 13.00 | 12.00 | 12.50 | 12.50 | | | | |
| 22 | 10.70 | 10.00 | 11.40 | 10.70 | 12.30 | 12.20 | 11.80 | 12.10 | | | | |
| 25 | 10.50 | 10.70 | 10.30 | 10.50 | | | | | | | | |

| t | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | |
|----|------------------|-------|-------|-------|------------------|-------|-------|-------|----|----|----|------|--|
| | LD-60(T2) | | | | HD-60(T2) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 13.50 | 13.70 | 13.80 | 13.67 | 8.90 | 9.00 | 8.80 | 8.90 | | | | | |
| 7 | 15.20 | 16.50 | 16.00 | 15.90 | 11.80 | 11.80 | 11.80 | 11.80 | | | | | |
| 10 | 18.90 | 18.00 | 18.60 | 18.50 | 17.00 | 19.50 | 18.40 | 18.30 | | | | | |
| 13 | 17.00 | 17.00 | 16.80 | 16.93 | 15.90 | 19.00 | 17.60 | 17.50 | | | | | |
| 16 | 17.10 | 15.00 | 16.20 | 16.10 | 15.00 | 17.00 | 16.00 | 16.00 | | | | | |
| 19 | 14.10 | 14.50 | 14.30 | 14.30 | 15.30 | 13.20 | 14.40 | 14.30 | | | | | |
| 22 | 12.30 | 11.20 | 13.40 | 12.30 | 14.20 | 12.90 | 12.50 | 13.20 | | | | | |
| 25 | 12.00 | 12.00 | 12.00 | 12.00 | | | | | | | | | |
| | LD-60(T3) | | | | HD-60(T3) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 13.00 | 13.50 | 13.40 | 13.30 | 9.50 | 9.30 | 9.70 | 9.50 | | | | | |
| 7 | 16.90 | 14.50 | 15.70 | 15.70 | 13.50 | 13.60 | 13.40 | 13.50 | | | | | |
| 10 | 19.00 | 18.80 | 19.20 | 19.00 | 17.50 | 21.00 | 19.40 | 19.30 | | | | | |
| 13 | 16.00 | 14.50 | 15.40 | 15.30 | 18.00 | 17.00 | 17.50 | 17.50 | | | | | |
| 16 | 12.60 | 12.90 | 16.20 | 13.90 | 16.40 | 16.70 | 15.50 | 16.20 | | | | | |
| 19 | 11.80 | 13.60 | 12.70 | 12.70 | 16.00 | 15.10 | 14.30 | 15.13 | | | | | |
| 22 | 12.40 | 12.70 | 12.10 | 12.40 | 15.00 | 14.20 | 13.50 | 14.23 | | | | | |
| | LD-80(T0) | | | | HD-80(T0) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 10.00 | 10.30 | 9.70 | 10.00 | 9.50 | 9.40 | 9.60 | 9.50 | | | | | |
| 7 | 14.50 | 15.00 | 14.90 | 14.80 | 13.50 | 15.50 | 14.50 | 14.50 | | | | | |
| 10 | 15.00 | 16.00 | 15.50 | 15.50 | 15.10 | 15.40 | 15.40 | 15.30 | | | | | |
| 13 | 16.90 | 16.70 | 17.10 | 16.90 | 17.60 | 17.60 | 17.60 | 17.60 | | | | | |
| 16 | 18.00 | 18.20 | 18.30 | 18.17 | 17.00 | 17.20 | 16.80 | 17.00 | | | | | |
| 19 | 16.50 | 16.50 | 16.50 | 16.50 | 14.70 | 12.70 | 13.70 | 13.70 | | | | | |
| 22 | 13.50 | 13.40 | 16.00 | 14.30 | 12.70 | 12.80 | 12.90 | 12.80 | | | | | |
| 25 | 13.70 | 14.10 | 13.90 | 13.90 | 12.00 | 12.30 | 11.70 | 12.00 | | | | | |
| 28 | 14.00 | 13.80 | 12.70 | 13.50 | | | | | | | | | |
| | LD-80(T1) | | | | HD-80(T1) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 9.50 | 9.30 | 9.70 | 9.50 | 9.50 | 9.30 | 9.70 | 9.50 | | | | | |
| 7 | 11.70 | 11.50 | 9.80 | 11.00 | 11.80 | 11.80 | 11.80 | 11.80 | | | | | |
| 10 | 18.00 | 17.50 | 17.90 | 17.80 | 17.80 | 16.10 | 17.10 | 17.00 | | | | | |
| 13 | 15.00 | 13.30 | 16.70 | 15.00 | 15.00 | 13.00 | 20.60 | 16.20 | | | | | |
| 16 | 15.00 | 15.00 | 12.60 | 14.20 | 16.10 | 16.30 | 9.60 | 14.00 | | | | | |
| 19 | 14.50 | 12.00 | 13.40 | 13.30 | 12.60 | 12.90 | 12.90 | 12.80 | | | | | |
| 22 | 13.00 | 13.40 | 12.60 | 13.00 | 12.00 | 12.50 | 12.10 | 12.20 | | | | | |
| 25 | 12.90 | 13.10 | 12.80 | 12.93 | | | | | | | | | |
| | LD-80(T2) | | | | HD-80(T2) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 8.50 | 8.30 | 8.70 | 8.50 | 9.50 | 9.10 | 9.90 | 9.50 | | | | | |
| 7 | 11.30 | 11.50 | 11.40 | 11.40 | 11.00 | 11.20 | 11.10 | 11.10 | | | | | |
| 10 | 16.90 | 15.00 | 16.10 | 16.00 | 17.00 | 16.90 | 17.10 | 17.00 | | | | | |
| 13 | 18.00 | 18.30 | 17.70 | 18.00 | 15.00 | 16.00 | 17.00 | 16.00 | | | | | |
| 16 | 12.00 | 13.50 | 22.20 | 15.90 | 16.50 | 15.50 | 10.90 | 14.30 | | | | | |
| 19 | 16.40 | 15.30 | 6.70 | 12.80 | 15.00 | 12.90 | 14.10 | 14.00 | | | | | |
| 22 | 12.00 | 12.90 | 12.60 | 12.50 | 13.30 | 13.70 | 12.90 | 13.30 | | | | | |
| 25 | 12.50 | 12.10 | 12.40 | 12.33 | | | | | | | | | |
| | LD-80(T3) | | | | HD-80(T3) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 9.50 | 9.10 | 9.90 | 9.50 | 9.50 | 9.10 | 9.90 | 9.50 | | | | | |
| 7 | 12.50 | 14.00 | 13.40 | 13.30 | 11.00 | 12.00 | 11.50 | 11.50 | | | | | |
| 10 | 18.60 | 19.00 | 18.20 | 18.60 | 16.00 | 15.90 | 16.10 | 16.00 | | | | | |
| 13 | 16.20 | 15.00 | 16.80 | 16.00 | 16.60 | 14.00 | 19.20 | 16.60 | | | | | |
| 16 | 16.00 | 16.00 | 14.80 | 15.60 | 14.00 | 12.50 | 13.40 | 13.30 | | | | | |
| 19 | 14.10 | 14.50 | 14.30 | 14.30 | 13.10 | 12.00 | 12.70 | 12.60 | | | | | |
| 22 | 13.00 | 13.00 | 13.30 | 13.10 | 12.00 | 11.90 | 11.80 | 11.90 | | | | | |

Table C2 Total soluble solids under brick & sand storage conditions

| Storage Period, t | Treatment replications | | | | | | | | | | | |
|-------------------|------------------------|-------|-------|-------|------------------|-------|-------|-------|------------------------|-------|-------|-------|
| | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. |
| | LD-40(T0) | | | | HD-40(T0) | | | | S-60(T0) | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 |
| 4 | 13.00 | 12.80 | 12.90 | 12.90 | 12.90 | 12.70 | 12.80 | 12.80 | 10.10 | 10.10 | 10.10 | 10.10 |
| 7 | 16.00 | 15.80 | 15.90 | 15.90 | 14.70 | 17.60 | 16.30 | 16.20 | 15.20 | 15.20 | 15.20 | 15.20 |
| 10 | 16.50 | 16.20 | 16.80 | 16.50 | 16.40 | 16.80 | 16.60 | 16.60 | 19.00 | 18.70 | 19.30 | 19.00 |
| 13 | 16.30 | 17.70 | 16.30 | 16.77 | 17.00 | 16.70 | 17.30 | 17.00 | 17.00 | 16.80 | 17.20 | 17.00 |
| 16 | 13.60 | 15.00 | 14.30 | 14.30 | 12.00 | 14.60 | 13.30 | 13.30 | 15.50 | 15.20 | 14.70 | 15.13 |
| 19 | 14.30 | 11.90 | 13.10 | 13.10 | 12.00 | 13.00 | 13.40 | 12.80 | 14.40 | 13.00 | 15.80 | 14.40 |
| 22 | 10.20 | 13.80 | 12.00 | 12.00 | 10.00 | 10.00 | 10.00 | 10.00 | 11.90 | 12.10 | 11.70 | 11.90 |
| 25 | 11.60 | 11.80 | 11.70 | 11.70 | | | | | 9.40 | 9.50 | 9.30 | 9.40 |
| | LD-40(T1) | | | | HD-40(T1) | | | | S-60(T1) | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 |
| 4 | 14.00 | 13.80 | 13.90 | 13.90 | 13.80 | 14.00 | 13.90 | 13.90 | 14.00 | 13.80 | 13.90 | 13.90 |
| 7 | 16.50 | 16.80 | 17.70 | 17.00 | 17.50 | 17.00 | 18.00 | 17.50 | 14.80 | 14.60 | 17.40 | 15.60 |
| 10 | 18.50 | 15.80 | 17.30 | 17.20 | 18.60 | 18.00 | 19.20 | 18.60 | 16.50 | 16.00 | 16.40 | 16.30 |
| 13 | 17.40 | 19.00 | 18.20 | 18.20 | 15.00 | 14.00 | 16.00 | 15.00 | 13.00 | 12.80 | 18.60 | 14.80 |
| 16 | 15.50 | 15.50 | 15.50 | 15.50 | 12.80 | 13.20 | 13.00 | 13.00 | 15.60 | 16.00 | 7.40 | 13.00 |
| 19 | 13.90 | 11.20 | 15.10 | 13.40 | 12.60 | 12.10 | 13.10 | 12.60 | 15.80 | 12.40 | 9.00 | 12.40 |
| 22 | 10.00 | 11.30 | 10.50 | 10.60 | 10.80 | 10.60 | 11.00 | 10.80 | 11.90 | 11.70 | 12.10 | 11.90 |
| | LD-40(T2) | | | | HD-40(T2) | | | | S-60(T2) | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 |
| 4 | 12.00 | 12.00 | 12.00 | 12.00 | 15.00 | 14.50 | 15.50 | 15.00 | 12.00 | 11.80 | 11.90 | 11.90 |
| 7 | 17.10 | 17.90 | 17.50 | 17.50 | 17.70 | 17.20 | 18.20 | 17.70 | 15.90 | 15.80 | 16.00 | 15.90 |
| 10 | 15.20 | 15.50 | 14.90 | 15.20 | 14.40 | 14.80 | 19.70 | 16.30 | 16.50 | 16.70 | 16.30 | 16.50 |
| 13 | 14.70 | 14.90 | 14.50 | 14.70 | 15.00 | 14.90 | 15.10 | 15.00 | 15.80 | 15.90 | 15.70 | 15.80 |
| 16 | 14.70 | 12.10 | 11.00 | 12.60 | 12.50 | 15.50 | 14.00 | 14.00 | 14.60 | 14.40 | 14.80 | 14.60 |
| 19 | 9.80 | 11.00 | 10.40 | 10.40 | 10.40 | 11.00 | 10.70 | 10.70 | 14.10 | 13.90 | 14.30 | 14.10 |
| 22 | 10.00 | 10.00 | 10.00 | 10.00 | 10.50 | 10.50 | 10.50 | 10.50 | 12.70 | 12.50 | 12.90 | 12.70 |
| | LD-40(T3) | | | | HD-40(T3) | | | | S-60(T3) | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 |
| 4 | 11.70 | 11.00 | 10.90 | 11.20 | 14.00 | 14.00 | 14.00 | 14.00 | 11.00 | 10.80 | 10.90 | 10.90 |
| 7 | 16.00 | 15.70 | 16.00 | 15.90 | 15.00 | 14.90 | 15.10 | 15.00 | 17.80 | 17.50 | 18.10 | 17.80 |
| 10 | 13.50 | 12.80 | 18.70 | 15.00 | 16.40 | 16.60 | 16.50 | 16.50 | 16.70 | 16.40 | 17.00 | 16.70 |
| 13 | 12.10 | 17.00 | 14.40 | 14.50 | 15.00 | 15.00 | 15.00 | 15.00 | 16.10 | 15.80 | 16.40 | 16.10 |
| 16 | 15.00 | 13.30 | 12.20 | 13.50 | 12.50 | 15.00 | 13.90 | 13.80 | 13.40 | 13.20 | 13.60 | 13.40 |
| 19 | 14.50 | 13.00 | 10.90 | 12.80 | 12.40 | 13.40 | 12.90 | 12.90 | 12.80 | 12.40 | 13.20 | 12.80 |
| 22 | 11.30 | 11.10 | 10.60 | 11.00 | 12.30 | 12.50 | 12.40 | 12.40 | 12.60 | 12.50 | 12.70 | 12.60 |
| | LD-60(T0) | | | | HD-60(T0) | | | | Non-wrapped (T) | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 |
| 4 | 11.00 | 11.00 | 11.00 | 11.00 | 10.40 | 10.60 | 10.50 | 10.50 | 11.40 | 11.20 | 11.30 | 11.30 |
| 7 | 14.20 | 14.20 | 14.40 | 14.27 | 15.70 | 14.50 | 15.10 | 15.10 | 17.00 | 17.00 | 17.00 | 17.00 |
| 10 | 17.00 | 18.00 | 17.50 | 17.50 | 16.00 | 15.80 | 16.20 | 16.00 | 17.00 | 17.80 | 17.40 | 17.40 |
| 13 | 19.80 | 19.40 | 20.20 | 19.80 | 17.40 | 17.40 | 17.40 | 17.40 | | | | |
| 16 | 16.60 | 16.20 | 17.00 | 16.60 | 15.00 | 14.90 | 15.10 | 15.00 | | | | |
| 19 | 14.90 | 14.70 | 15.10 | 14.90 | 13.60 | 15.00 | 14.30 | 14.30 | | | | |
| 22 | 14.80 | 14.20 | 15.40 | 14.80 | 13.00 | 13.00 | 13.60 | 13.20 | | | | |
| 25 | 14.00 | 13.70 | 14.30 | 14.00 | 11.00 | 13.20 | 12.10 | 12.10 | | | | |
| 28 | 13.30 | 13.00 | 12.90 | 13.07 | | | | | | | | |
| | LD-60(T1) | | | | HD-60(T1) | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 11.10 | 12.70 | 11.90 | 11.90 | | | | |
| 7 | 14.90 | 13.80 | 16.00 | 14.90 | 14.10 | 13.80 | 14.10 | 14.00 | | | | |
| 10 | 17.00 | 16.50 | 17.50 | 17.00 | 17.60 | 17.60 | 17.60 | 17.60 | | | | |
| 13 | 19.70 | 17.60 | 19.10 | 18.80 | 12.00 | 17.00 | 18.40 | 15.80 | | | | |
| 16 | 13.80 | 13.60 | 14.00 | 13.80 | 14.00 | 13.80 | 14.20 | 14.00 | | | | |
| 19 | 13.40 | 15.40 | 11.40 | 13.40 | 14.00 | 12.50 | 13.40 | 13.30 | | | | |
| 22 | 14.20 | 12.70 | 11.20 | 12.70 | 13.20 | 13.40 | 12.40 | 13.00 | | | | |
| 25 | 13.00 | 11.80 | 12.60 | 12.47 | | | | | | | | |

| t | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | R1 | R2 | R3 | AVG. | |
|----|------------------|-------|-------|-------|------------------|-------|-------|-------|----|----|----|------|--|
| | LD-80(T2) | | | | HD-80(T2) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 10.00 | 12.00 | 11.00 | 11.00 | 12.00 | 11.90 | 12.10 | 12.00 | | | | | |
| 7 | 16.00 | 18.00 | 17.00 | 17.00 | 15.70 | 13.50 | 14.60 | 14.60 | | | | | |
| 10 | 16.50 | 16.40 | 16.60 | 16.50 | 15.20 | 15.20 | 15.20 | 15.20 | | | | | |
| 13 | 14.50 | 14.30 | 14.70 | 14.50 | 14.90 | 14.80 | 15.00 | 14.90 | | | | | |
| 16 | 13.50 | 13.80 | 13.20 | 13.50 | 14.00 | 13.70 | 14.30 | 14.00 | | | | | |
| 19 | 12.00 | 12.20 | 11.90 | 12.03 | 14.20 | 12.20 | 13.20 | 13.20 | | | | | |
| 22 | 10.80 | 10.70 | 10.90 | 10.80 | 12.80 | 12.60 | 13.00 | 12.80 | | | | | |
| 25 | 10.50 | 10.70 | 10.30 | 10.50 | | | | | | | | | |
| | LD-80(T3) | | | | HD-80(T3) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 11.00 | 10.80 | 10.90 | 10.90 | 13.00 | 12.80 | 12.90 | 12.90 | | | | | |
| 7 | 19.00 | 18.80 | 18.90 | 18.90 | 14.20 | 14.00 | 14.40 | 14.20 | | | | | |
| 10 | 18.70 | 19.20 | 19.10 | 19.00 | 16.70 | 16.10 | 17.30 | 16.70 | | | | | |
| 13 | 17.00 | 15.00 | 19.60 | 17.20 | 13.00 | 12.70 | 13.30 | 13.00 | | | | | |
| 16 | 15.20 | 15.10 | 15.30 | 15.20 | 14.00 | 11.00 | 12.50 | 12.50 | | | | | |
| 19 | 13.80 | 10.60 | 17.00 | 13.80 | 12.10 | 12.40 | 12.40 | 12.30 | | | | | |
| 22 | 10.80 | 10.60 | 11.00 | 10.80 | 11.80 | 12.00 | 12.20 | 12.00 | | | | | |
| | LD-80(T0) | | | | HD-80(T0) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 11.80 | 11.60 | 11.70 | 11.70 | 15.00 | 15.00 | 15.00 | 15.00 | | | | | |
| 7 | 14.70 | 14.30 | 14.50 | 14.50 | 16.70 | 15.00 | 18.40 | 16.70 | | | | | |
| 10 | 16.60 | 13.00 | 20.20 | 16.60 | 17.00 | 17.80 | 16.20 | 17.00 | | | | | |
| 13 | 18.50 | 18.40 | 18.60 | 18.50 | 18.00 | 16.00 | 20.00 | 18.00 | | | | | |
| 16 | 19.00 | 18.90 | 19.10 | 19.00 | 13.00 | 14.90 | 14.10 | 14.00 | | | | | |
| 19 | 17.00 | 16.50 | 16.30 | 16.60 | 13.00 | 13.90 | 12.10 | 13.00 | | | | | |
| 22 | 14.80 | 14.00 | 15.10 | 14.63 | 12.00 | 12.70 | 11.90 | 12.20 | | | | | |
| 25 | 12.90 | 13.70 | 13.30 | 13.30 | 13.50 | 11.00 | 10.60 | 11.70 | | | | | |
| 28 | 13.40 | 11.20 | 12.30 | 12.30 | | | | | | | | | |
| | LD-80(T1) | | | | HD-80(T1) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 15.00 | 15.20 | 15.10 | 15.10 | | | | | |
| 7 | 14.50 | 14.40 | 14.60 | 14.50 | 17.40 | 15.80 | 16.60 | 16.60 | | | | | |
| 10 | 15.20 | 15.20 | 15.20 | 15.20 | 17.60 | 17.30 | 17.90 | 17.60 | | | | | |
| 13 | 17.50 | 17.30 | 17.70 | 17.50 | 17.10 | 16.90 | 17.30 | 17.10 | | | | | |
| 16 | 14.00 | 13.90 | 14.10 | 14.00 | 14.20 | 17.10 | 11.30 | 14.20 | | | | | |
| 19 | 12.90 | 12.90 | 12.80 | 12.87 | 10.50 | 13.60 | 12.20 | 12.10 | | | | | |
| 22 | 12.00 | 11.70 | 12.30 | 12.00 | 11.70 | 12.10 | 11.60 | 11.80 | | | | | |
| 25 | 11.00 | 10.90 | 11.10 | 11.00 | | | | | | | | | |
| | LD-80(T2) | | | | HD-80(T2) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 14.00 | 15.00 | 14.50 | 14.50 | 14.50 | 15.00 | 14.90 | 14.80 | | | | | |
| 7 | 18.80 | 17.20 | 18.00 | 18.00 | 18.30 | 16.90 | 17.60 | 17.60 | | | | | |
| 10 | 16.00 | 15.90 | 16.10 | 16.00 | 17.80 | 17.20 | 17.50 | 17.50 | | | | | |
| 13 | 14.50 | 14.50 | 14.80 | 14.60 | 16.50 | 16.10 | 16.90 | 16.50 | | | | | |
| 16 | 13.10 | 13.00 | 13.20 | 13.10 | 13.80 | 13.60 | 14.00 | 13.80 | | | | | |
| 19 | 12.00 | 11.90 | 12.10 | 12.00 | 13.00 | 12.90 | 13.10 | 13.00 | | | | | |
| 22 | 11.90 | 11.80 | 12.10 | 11.93 | 11.20 | 11.10 | 11.30 | 11.20 | | | | | |
| 25 | 12.20 | 9.50 | 11.00 | 10.90 | | | | | | | | | |
| | LD-80(T3) | | | | HD-80(T3) | | | | | | | | |
| 1 | 7.00 | 6.90 | 7.10 | 7.00 | 7.00 | 6.90 | 7.10 | 7.00 | | | | | |
| 4 | 13.00 | 13.00 | 13.00 | 13.00 | 12.00 | 12.20 | 12.10 | 12.10 | | | | | |
| 7 | 15.90 | 18.40 | 17.30 | 17.20 | 17.00 | 18.50 | 17.90 | 17.80 | | | | | |
| 10 | 15.70 | 15.90 | 15.80 | 15.80 | 15.50 | 15.80 | 15.80 | 15.70 | | | | | |
| 13 | 14.50 | 14.70 | 13.70 | 14.30 | 15.00 | 14.80 | 14.90 | 14.90 | | | | | |
| 16 | 13.20 | 13.00 | 13.40 | 13.20 | 14.40 | 17.40 | 11.40 | 14.40 | | | | | |
| 19 | 12.20 | 12.00 | 12.40 | 12.20 | 14.00 | 13.80 | 14.20 | 14.00 | | | | | |
| 22 | 10.80 | 10.70 | 10.90 | 10.80 | 11.00 | 11.00 | 11.00 | 11.00 | | | | | |

Table C3 Total soluble solids under cold storage conditions

| storage period, t | Treatment Replications | | | | | | | | |
|----------------------|------------------------|------|------|-----------|------|------|----------|------|------|
| | R1 | R2 | AVG. | R1 | R2 | AVG. | R1 | R2 | AVG. |
| | HD-40(T0) | | | LD-40(T0) | | | S-60(T0) | | |
| 1 | 6.8 | 7.2 | 7.0 | 6.8 | 7.2 | 7.0 | 6.8 | 7.2 | 7.0 |
| 15 | 15.0 | 16.0 | 15.5 | 15.5 | 17.5 | 16.5 | 15.0 | 15.0 | 15.0 |
| 22 | 18.0 | 16.8 | 17.4 | 17.2 | 18.2 | 17.7 | 16.7 | 17.7 | 17.2 |
| 30 | 14.0 | 15.4 | 14.7 | 16.4 | 16.6 | 16.5 | 14.1 | 13.5 | 13.8 |
| | HD-40(T1) | | | LD-40(T1) | | | S-60(T1) | | |
| 1 | 6.8 | 7.2 | 7.0 | 6.8 | 7.2 | 7.0 | 6.8 | 7.2 | 7.0 |
| 15 | 14.1 | 15.5 | 14.8 | 18.8 | 20.0 | 19.4 | 15.2 | 14.8 | 15.0 |
| 22 | 22.0 | 22.6 | 22.3 | 19.8 | 19.6 | 19.7 | 19.4 | 19.4 | 19.4 |
| 30 | 14.3 | 15.4 | 14.9 | 13.4 | 14.2 | 13.8 | 14.9 | 15.5 | 15.2 |
| | HD-60(T0) | | | LD-60(T0) | | | | | |
| 1 | 6.8 | 7.2 | 7.0 | 6.8 | 7.2 | 7.0 | | | |
| 15 | 17.8 | 17.0 | 17.4 | 16.5 | 17.3 | 16.9 | | | |
| 22 | 18.2 | 19.8 | 19.0 | 17.3 | 17.7 | 17.5 | | | |
| 30 | 12.0 | 13.2 | 12.6 | 14.6 | 14.2 | 14.4 | | | |
| | HD-60(T1) | | | LD-60(T1) | | | | | |
| 1 | 6.8 | 7.2 | 7.0 | 6.8 | 7.2 | 7.0 | | | |
| 15 | 14.1 | 14.9 | 14.5 | 16.5 | 16.7 | 16.6 | | | |
| 22 | 18.3 | 17.5 | 17.9 | 16.9 | 17.5 | 17.2 | | | |
| 30 | 17.2 | 17.8 | 17.5 | 14.4 | 15.0 | 14.7 | | | |
| | HD-80(T0) | | | LD-80(T0) | | | | | |
| 1 | 6.8 | 7.2 | 7.0 | 6.8 | 7.2 | 7.0 | | | |
| 15 | 12.8 | 14.0 | 13.4 | 16.3 | 17.5 | 16.9 | | | |
| 22 | 16.2 | 16.6 | 16.4 | 18.7 | 19.3 | 19.0 | | | |
| 30 | 11.2 | 13.2 | 12.2 | 17.1 | 17.7 | 17.4 | | | |
| | HD-80(T1) | | | LD-80(T1) | | | | | |
| 1 | 6.8 | 7.2 | 7.0 | 6.8 | 7.2 | 7.0 | | | |
| 15 | 13.6 | 12.0 | 12.8 | 17.3 | 17.5 | 17.4 | | | |
| 22 | 14.1 | 12.9 | 13.5 | 19.3 | 18.1 | 18.7 | | | |
| 30 | 14.5 | 14.9 | 14.7 | 15.7 | 16.3 | 16.0 | | | |

APPENDIX - D

Table D1 Decay under room temperature storage conditions

| Storage Period, t | Treatment replications | | | | | | | | |
|-------------------|------------------------|---------|--------|-----------|--------|--------|-----------------|--------|---------|
| | R1 | R2 | AVG. | R1 | R2 | AVG. | R1 | R2 | AVG. |
| | LD-40(T0) | | | HD-40(T0) | | | S-60(T0) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | 9.80 | - | 4.90 | 3.25 | 7.97 | 5.61 | - | - | - |
| 16 | 9.40 | 2.74 | 6.07 | 7.85 | 14.25 | 11.05 | 14.23 | 19.63 | 16.93 |
| 19 | 15.46 | 20.38 | 17.92 | 29.20 | 33.26 | 31.23 | 56.73 | 61.95 | 59.34 |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| | LD-40(T1) | | | HD-40(T1) | | | S-60(T1) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | 5.06 | 6.68 | 5.87 | 7.24 | - | 3.62 | 22.22 | 31.86 | 27.04 |
| 16 | 7.84 | 8.84 | 8.34 | 10.72 | 25.10 | 17.91 | 100.00 | 100.00 | 100.00 |
| 19 | 23.61 | 30.62 | 27.12 | 29.17 | 46.51 | 37.84 | - | - | - |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | - | - | - |
| | LD-40(T2) | | | HD-40(T2) | | | S-60(T2) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | 6.66 | 7.65 | 7.16 | 6.01 | 8.36 | 7.18 | 68.11 | 50.92 | 59.51 |
| 16 | 18.87 | 11.24 | 15.06 | 6.01 | 22.65 | 14.33 | 100.00 | 100.00 | 100.00 |
| 19 | 41.66 | 61.02 | 51.34 | 48.35 | 64.67 | 56.51 | - | - | - |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | - | - | - |
| | LD-40(T3) | | | HD-40(T3) | | | S-60(T3) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | 11.09 | 14.16 | 12.63 |
| 13 | 5.99 | 6.47 | 6.23 | 3.12 | 3.57 | 3.35 | 24.43 | 26.07 | 25.25 |
| 16 | 31.32 | 37.99 | 34.65 | 8.93 | 11.41 | 10.17 | 100.00 | 100.00 | 100.00 |
| 19 | 63.33 | 71.34 | 67.34 | 53.64 | 68.48 | 61.06 | - | - | - |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | - | - | - |
| | LD-60(T0) | | | HD-60(T0) | | | Non-wrapped (T) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | 5.7 | #VALUE! |
| 10 | - | - | - | - | - | - | 6.88 | 10.12 | 8.5 |
| 13 | - | - | - | - | - | - | - | - | - |
| 16 | - | #VALUE! | 3.21 | 12.39 | 19.68 | 16.04 | - | - | - |
| 19 | 7.14 | 11.45 | 9.29 | 32.42 | 23.00 | 27.71 | - | - | - |
| 22 | 26.12 | 28.73 | 27.42 | 100.00 | 100.00 | 100.00 | - | - | - |
| 25 | 100.00 | 100.00 | 100.00 | - | - | - | - | - | - |
| | LD-60(T1) | | | HD-60(T1) | | | | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | - | - | - | - | - | - | - | - | - |
| 16 | - | - | - | 8.61 | 14.43 | 11.52 | - | - | - |
| 19 | 8.88 | 11.67 | 10.28 | 32.46 | 33.93 | 33.20 | - | - | - |
| 22 | 27.09 | 31.50 | 29.30 | 100.00 | 100.00 | 100.00 | - | - | - |
| 25 | 100.00 | 100.00 | 100.00 | - | - | - | - | - | - |

| t | R1 | R2 | AVG. | R1 | R2 | AVG. | R1 | R2 | AVG. |
|----|------------------|--------|--------|------------------|--------|--------|----|----|------|
| | LD-60(T2) | | | HD-60(T2) | | | | | |
| 1 | - | - | - | - | - | - | | | |
| 4 | - | - | - | - | - | - | | | |
| 7 | - | - | - | - | - | - | | | |
| 10 | - | - | - | - | - | - | | | |
| 13 | - | - | - | - | - | - | | | |
| 16 | - | - | - | 18.99 | 21.77 | 20.38 | | | |
| 19 | 8.93 | 12.70 | 10.82 | 50.50 | 59.69 | 55.10 | | | |
| 22 | 47.77 | 59.77 | 53.77 | 100.00 | 100.00 | 100.00 | | | |
| 25 | 100.00 | 100.00 | 100.00 | | | | | | |
| | LD-60(T3) | | | HD-60(T3) | | | | | |
| 1 | - | - | - | - | - | - | | | |
| 4 | - | - | - | - | - | - | | | |
| 7 | - | - | - | - | - | - | | | |
| 10 | - | - | - | - | - | - | | | |
| 13 | 6.50 | - | 3.25 | 5.36 | 7.07 | 6.22 | | | |
| 16 | 21.93 | 19.35 | 20.64 | 30.33 | 43.79 | 37.06 | | | |
| 19 | 52.12 | 53.68 | 52.90 | 55.07 | 63.78 | 59.42 | | | |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | | | |
| | LD-80(T0) | | | HD-80(T0) | | | | | |
| 1 | - | - | - | - | - | - | | | |
| 4 | - | - | - | - | - | - | | | |
| 7 | - | - | - | - | - | - | | | |
| 10 | - | - | - | - | - | - | | | |
| 13 | - | - | - | - | - | - | | | |
| 16 | - | - | - | 6.03 | 8.34 | 7.19 | | | |
| 19 | 5.63 | 13.55 | 9.59 | 20.44 | 41.38 | 30.91 | | | |
| 22 | 25.66 | 31.27 | 28.46 | 53.99 | 77.91 | 65.95 | | | |
| 25 | 38.77 | 44.12 | 41.44 | 100.00 | 100.00 | 100.00 | | | |
| 28 | 100.00 | 100.00 | 100.00 | | | | | | |
| | LD-80(T1) | | | HD-80(T1) | | | | | |
| 1 | - | - | - | - | - | - | | | |
| 4 | - | - | - | - | - | - | | | |
| 7 | - | - | - | - | - | - | | | |
| 10 | - | - | - | - | - | - | | | |
| 13 | - | - | - | 13.50 | - | 6.75 | | | |
| 16 | 8.42 | - | 4.21 | 20.22 | 28.06 | 24.14 | | | |
| 19 | 9.55 | 3.68 | 6.61 | 30.77 | 35.27 | 33.02 | | | |
| 22 | 24.44 | 29.99 | 27.21 | 100.00 | 100.00 | 100.00 | | | |
| 25 | 100.00 | 100.00 | 100.00 | | | | | | |
| | LD-80(T2) | | | HD-80(T2) | | | | | |
| 1 | - | - | - | - | - | - | | | |
| 4 | - | - | - | - | - | - | | | |
| 7 | - | - | - | - | - | - | | | |
| 10 | - | - | - | - | - | - | | | |
| 13 | - | - | - | - | - | - | | | |
| 16 | - | - | - | 9.31 | 15.31 | 12.31 | | | |
| 19 | 12.70 | - | 6.35 | 43.81 | 49.05 | 46.43 | | | |
| 22 | 45.57 | 40.19 | 42.88 | 100.00 | 100.00 | 100.00 | | | |
| 25 | 100.00 | 100.00 | 100.00 | | | | | | |
| | LD-80(T3) | | | HD-80(T3) | | | | | |
| 1 | - | - | - | - | - | - | | | |
| 4 | - | - | - | - | - | - | | | |
| 7 | - | - | - | - | - | - | | | |
| 10 | - | - | - | - | - | - | | | |
| 13 | - | - | - | 8.17 | 12.33 | 10.25 | | | |
| 16 | 18.85 | 22.46 | 20.66 | 19.88 | 27.95 | 23.92 | | | |
| 19 | 41.65 | 50.00 | 45.83 | 42.97 | 55.37 | 49.17 | | | |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | | | |

Table D2 Decay under brick & sand storage conditions

| Storage Period, t | Treatment replications | | | | | | | | |
|-------------------|------------------------|--------|--------|------------------|--------|--------|------------------------|--------|--------|
| | R1 | R2 | AVG. | R1 | R2 | AVG. | R1 | R2 | AVG. |
| | LD-40(T0) | | | HD-40(T0) | | | S-60(T0) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 10 | 4.44 | 9.16 | 6.80 | - | - | - | - | - | - |
| 13 | 9.70 | 15.96 | 12.83 | 6.71 | 9.11 | 7.91 | 5.58 | - | 2.79 |
| 16 | 32.88 | 37.70 | 35.29 | 11.98 | 14.65 | 13.31 | 7.77 | 10.86 | 9.32 |
| 19 | 60.66 | 68.66 | 64.66 | 29.33 | 34.50 | 31.92 | 34.82 | 37.42 | 36.12 |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 89.68 | 72.80 | 81.24 |
| | LD-40(T1) | | | HD-40(T1) | | | S-60(T1) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | 5.55 | 8.82 | 7.18 | 4.01 | 6.23 | 5.12 | 12.79 | 16.17 | 14.48 |
| 16 | 12.07 | 18.12 | 15.09 | 20.11 | 26.55 | 23.33 | 37.33 | 42.38 | 39.86 |
| 19 | 39.39 | 47.70 | 43.54 | 40.29 | 51.46 | 45.87 | 100.00 | 100.00 | 100.00 |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | - | - | - |
| | LD-40(T2) | | | HD-40(T2) | | | S-60(T2) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | 14.99 | 15.38 | 15.18 |
| 13 | 12.56 | - | 6.28 | 4.32 | 6.32 | 5.32 | 29.47 | 23.23 | 26.35 |
| 16 | 22.11 | 12.35 | 17.23 | 16.91 | 26.51 | 21.71 | 52.55 | 41.57 | 47.06 |
| 19 | 45.66 | 47.94 | 46.80 | 36.88 | 47.24 | 42.06 | 100.00 | 100.00 | 100.00 |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | - | - | - |
| | LD-40(T3) | | | HD-40(T3) | | | S-60(T3) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 10 | 5.00 | - | 2.50 | 4.22 | - | 2.11 | 13.88 | 8.34 | 11.11 |
| 13 | 13.47 | 21.33 | 17.40 | 16.87 | 9.98 | 13.43 | 42.59 | 55.42 | 49.01 |
| 16 | 30.63 | 41.73 | 36.18 | 50.06 | 65.39 | 57.72 | 78.88 | 99.02 | 88.95 |
| 19 | 55.73 | 67.89 | 61.81 | 69.24 | 84.58 | 76.91 | 100.00 | 100.00 | 100.00 |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | - | - | - |
| | LD-60(T0) | | | HD-60(T0) | | | Non-wrapped (T) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | 10.82 | - | 5.41 |
| 7 | - | - | - | - | - | - | 16.70 | 10.50 | 13.60 |
| 10 | - | - | - | - | - | - | 100.00 | 100.00 | 100.00 |
| 13 | - | - | - | 4.34 | 1.00 | 2.67 | - | - | - |
| 16 | 6.46 | - | 3.23 | 12.99 | 15.49 | 14.24 | - | - | - |
| 19 | 6.46 | 6.27 | 6.37 | 34.77 | 38.92 | 36.85 | - | - | - |
| 22 | 33.88 | 65.63 | 49.75 | 52.44 | 61.32 | 56.88 | - | - | - |
| 25 | 65.76 | 98.38 | 82.07 | 100.00 | 100.00 | 100.00 | - | - | - |
| 28 | 100.00 | 100.00 | 100.00 | - | - | - | - | - | - |
| | LD-60(T1) | | | HD-60(T1) | | | | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | 7.06 | - | 3.53 | 8.60 | - | 4.30 | - | - | - |
| 16 | 22.27 | 27.76 | 25.01 | 11.41 | 15.48 | 13.44 | - | - | - |
| 19 | 42.74 | 19.46 | 31.10 | 28.09 | 33.97 | 31.03 | - | - | - |
| 22 | 53.33 | 63.43 | 58.38 | 100.00 | 100.00 | 100.00 | - | - | - |
| 25 | 100.00 | 100.00 | 100.00 | - | - | - | - | - | - |

| t | R1 | R2 | AVG. | R1 | R2 | AVG. | R1 | R2 | AVG. |
|----|------------------|--------|--------|------------------|--------|--------|----|----|------|
| | LD-60(T2) | | | HD-60(T2) | | | | | |
| 1 | -- | -- | -- | -- | -- | -- | | | |
| 4 | -- | -- | -- | -- | -- | -- | | | |
| 7 | -- | -- | -- | -- | -- | -- | | | |
| 10 | 5.96 | -- | 2.98 | -- | -- | -- | | | |
| 13 | 14.28 | 22.28 | 18.28 | 4.00 | 5.26 | 4.63 | | | |
| 16 | 45.35 | 54.27 | 49.81 | 11.06 | 18.42 | 14.74 | | | |
| 19 | 68.92 | 95.47 | 82.20 | 35.55 | 43.92 | 39.73 | | | |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | | | |
| | LD-60(T3) | | | HD-60(T3) | | | | | |
| 1 | -- | -- | -- | -- | -- | -- | | | |
| 4 | -- | -- | -- | -- | -- | -- | | | |
| 7 | -- | -- | -- | -- | -- | -- | | | |
| 10 | 6.18 | -- | 3.09 | -- | -- | -- | | | |
| 13 | 15.79 | 19.78 | 17.79 | 4.65 | 15.41 | 10.03 | | | |
| 16 | 15.79 | 25.78 | 20.79 | 17.66 | 26.62 | 22.14 | | | |
| 19 | 39.84 | 49.09 | 44.46 | 35.52 | 48.36 | 41.94 | | | |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | | | |
| | LD-80(T0) | | | HD-80(T0) | | | | | |
| 1 | -- | -- | -- | -- | -- | -- | | | |
| 4 | -- | -- | -- | -- | -- | -- | | | |
| 7 | -- | -- | -- | -- | -- | -- | | | |
| 10 | -- | -- | -- | -- | -- | -- | | | |
| 13 | -- | -- | -- | -- | -- | -- | | | |
| 16 | 6.02 | -- | 3.01 | 11.13 | 13.16 | 12.15 | | | |
| 19 | 6.02 | 6.92 | 6.47 | 42.95 | 44.38 | 43.66 | | | |
| 22 | 24.05 | 23.11 | 23.58 | 42.95 | 52.37 | 47.66 | | | |
| 25 | 49.37 | 59.65 | 54.51 | 100.00 | 100.00 | 100.00 | | | |
| 28 | 100.00 | 100.00 | 100.00 | | | | | | |
| | LD-80(T1) | | | HD-80(T1) | | | | | |
| 1 | -- | -- | -- | -- | -- | -- | | | |
| 4 | -- | -- | -- | -- | -- | -- | | | |
| 7 | -- | -- | -- | -- | -- | -- | | | |
| 10 | -- | -- | -- | -- | -- | -- | | | |
| 13 | -- | -- | -- | 5.55 | 12.43 | 8.99 | | | |
| 16 | -- | -- | -- | 13.87 | 23.33 | 18.60 | | | |
| 19 | 10.46 | 18.87 | 14.66 | 30.33 | 45.45 | 37.89 | | | |
| 22 | 46.46 | 56.79 | 51.63 | 100.00 | 100.00 | 100.00 | | | |
| 25 | 100.00 | 100.00 | 100.00 | | | | | | |
| | LD-80(T2) | | | HD-80(T2) | | | | | |
| 1 | -- | -- | -- | -- | -- | -- | | | |
| 4 | -- | -- | -- | -- | -- | -- | | | |
| 7 | -- | -- | -- | -- | -- | -- | | | |
| 10 | -- | -- | -- | 5.28 | -- | 2.64 | | | |
| 13 | 9.84 | 5.38 | 7.61 | 5.28 | 20.00 | 12.64 | | | |
| 16 | 23.66 | 30.00 | 26.83 | 15.99 | 31.53 | 23.76 | | | |
| 19 | 40.77 | 53.16 | 46.97 | 45.78 | 31.20 | 38.49 | | | |
| 22 | 61.53 | 73.65 | 67.59 | 100.00 | 100.00 | 100.00 | | | |
| 25 | 100.00 | 100.00 | 100.00 | | | | | | |
| | LD-80(T3) | | | HD-80(T3) | | | | | |
| 1 | -- | -- | -- | -- | -- | -- | | | |
| 4 | -- | -- | -- | -- | -- | -- | | | |
| 7 | -- | -- | -- | -- | -- | -- | | | |
| 10 | -- | -- | -- | 5.14 | -- | 2.57 | | | |
| 13 | 4.28 | -- | 2.14 | 5.14 | 18.75 | 11.95 | | | |
| 16 | 14.79 | 10.47 | 12.63 | 17.01 | 26.83 | 21.92 | | | |
| 19 | 48.71 | 39.56 | 44.13 | 38.66 | 49.00 | 43.83 | | | |
| 22 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | | | |

Table D3 Decay under cold storage conditions

| Storage Period, t | Treatment replications | | | | | | | | |
|----------------------|------------------------|--------|--------|-----------------|--------|--------|------------------------|--------|--------|
| | R1 | R2 | AVG. | R1 | R2 | AVG. | R1 | R2 | AVG. |
| | LD-40(0) | | | HD-40(0) | | | S-60(0) | | |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | - | - | - | - | - | - | - | - | - |
| 16 | - | - | - | - | - | - | - | - | - |
| 19 | 24.52 | 32.54 | 28.53 | 22.58 | 27.39 | 24.98 | 23.68 | 27.70 | 25.69 |
| 22 | 40.10 | 42.42 | 41.26 | 33.87 | 37.45 | 35.66 | 33.38 | 38.66 | 36.02 |
| 25 | 50.15 | 55.83 | 52.99 | 44.52 | 50.16 | 47.34 | 41.41 | 45.31 | 43.36 |
| 28 | 62.14 | 65.30 | 63.72 | 59.63 | 66.41 | 63.02 | 53.07 | 48.39 | 50.73 |
| 31 | 69.69 | 73.24 | 71.46 | 71.88 | 79.53 | 75.70 | 54.52 | 51.60 | 53.06 |
| | LD-40(1) | | | HD-40(1) | | | S-60(1) | | |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | - | - | - | - | - | - | 14.77 | 20.73 | 17.75 |
| 16 | - | - | - | 21.71 | 31.90 | 26.80 | 25.82 | 18.14 | 21.98 |
| 19 | 28.51 | 33.95 | 31.23 | 45.88 | 55.15 | 50.52 | 34.44 | 23.52 | 28.98 |
| 22 | 41.45 | 52.12 | 46.79 | 68.65 | 80.36 | 74.50 | 59.18 | 49.70 | 54.44 |
| 25 | 60.34 | 70.44 | 65.39 | 80.09 | 99.85 | 89.97 | 69.71 | 67.63 | 68.67 |
| 28 | 80.82 | 95.60 | 88.21 | 100.00 | 100.00 | 100.00 | 75.16 | 72.67 | 73.91 |
| 31 | 100.00 | 100.00 | 100.00 | - | - | - | 84.19 | 89.45 | 86.82 |
| | LD-60(0) | | | HD-60(0) | | | Non-wrapped (T) | | |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | - | - | - | - | - | - | 9.25 | 17.83 | 13.54 |
| 16 | - | - | - | - | - | - | 19.46 | 28.04 | 23.75 |
| 19 | - | - | - | - | - | - | 44.89 | 60.05 | 52.47 |
| 22 | - | - | - | 26.22 | 25.11 | 25.66 | 100.00 | 100.00 | 100.00 |
| 25 | 15.90 | 18.64 | 17.27 | 33.18 | 36.00 | 34.59 | - | - | - |
| 28 | 33.81 | 37.51 | 35.66 | 43.33 | 51.73 | 47.53 | - | - | - |
| 31 | 54.09 | 50.25 | 52.17 | 60.44 | 54.74 | 57.59 | - | - | - |
| | LD-60(1) | | | HD-60(1) | | | | | |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | - | - | - | - | - | - | - | - | - |
| 16 | - | - | - | - | - | - | - | - | - |
| 19 | - | - | - | 19.79 | 26.22 | 23.00 | - | - | - |
| 22 | 18.66 | 24.03 | 21.35 | 30.73 | 37.95 | 34.34 | - | - | - |
| 25 | 24.29 | 31.43 | 27.86 | 50.54 | 44.88 | 47.71 | - | - | - |
| 28 | 42.49 | 52.97 | 47.73 | 60.66 | 57.48 | 59.07 | - | - | - |
| 31 | 51.15 | 61.88 | 56.52 | 75.12 | 69.75 | 72.43 | - | - | - |
| | LD-80(0) | | | HD-80(0) | | | | | |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | - | - | - | - | - | - | - | - | - |
| 16 | - | - | - | - | - | - | - | - | - |
| 19 | - | - | - | 24.63 | 27.78 | 26.20 | - | - | - |
| 22 | - | - | - | 29.31 | 33.81 | 31.56 | - | - | - |
| 25 | 20.76 | 24.34 | 22.55 | 37.99 | 41.87 | 39.93 | - | - | - |
| 28 | 47.40 | 49.66 | 48.53 | 49.33 | 48.25 | 47.79 | - | - | - |
| 31 | 50.14 | 53.38 | 51.76 | 52.87 | 58.45 | 55.66 | - | - | - |
| | LD-80(1) | | | HD-80(1) | | | | | |
| 10 | - | - | - | - | - | - | - | - | - |
| 13 | - | - | - | - | - | - | - | - | - |
| 16 | - | - | - | - | - | - | - | - | - |
| 19 | - | - | - | 41.74 | 56.91 | 49.33 | - | - | - |
| 22 | - | - | - | 41.74 | 64.08 | 52.91 | - | - | - |
| 25 | 43.55 | 51.84 | 47.69 | 53.68 | 60.46 | 57.07 | - | - | - |
| 28 | 54.45 | 58.23 | 56.34 | 61.39 | 67.79 | 64.59 | - | - | - |
| 31 | 62.99 | 70.35 | 66.67 | 73.58 | 65.78 | 69.68 | - | - | - |

APPENDIX - E

Table E1 Shrinkage under room temperature storage conditions

| Storage eriod(day) | Treatments replications | | | | | | | | |
|-----------------------|-------------------------|--------|--------|------------------|--------|--------|----------------------|--------|--------|
| | R1 | R2 | AVG. | R1 | R2 | AVG. | R1 | R2 | AVG. |
| | LD-40(T1) | | | HD-40(T1) | | | S-60(T1) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | 4.26 | 0 | 2.13 | 10.82 | 0.00 | 5.41 |
| 13 | 8.17 | 20.65 | 14.41 | 15.35 | 6.87 | 11.11 | 49.24 | 34.10 | 41.67 |
| 16 | 15.67 | 22.23 | 18.95 | 26.23 | 24.93 | 25.58 | 100 | 100 | 100.00 |
| 19 | 100 | 100 | 100.00 | 100 | 100 | 100.00 | | | |
| | LD-40(T2) | | | HD-40(T2) | | | S-60(T2) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | 5.03 | 6.23 | 5.63 | - | - | - | - | - | - |
| 10 | 14.21 | 16.9 | 15.56 | 22.57 | 28.49 | 25.53 | 13.98 | 36.71 | 25.35 |
| 13 | 26.52 | 33.95 | 30.23 | 44.67 | 35.33 | 40.00 | 44.34 | 52.80 | 48.57 |
| 16 | 100 | 100 | 100.00 | 100.00 | 100.00 | 100.00 | 100 | 100.00 | 100.00 |
| | LD-40(T3) | | | HD-40(T3) | | | S-60(T3) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | 4.41 | 4.11 | 4.26 | 0 | 10.16 | 5.08 | - | - | - |
| 10 | 13.88 | 21.68 | 17.78 | 23.25 | 36.33 | 29.79 | 20.85 | 37.9 | 29.37 |
| 13 | 57.49 | 49.49 | 53.49 | 58.45 | 52.67 | 55.56 | 56.91 | 76.4 | 66.67 |
| 16 | 100 | 100 | 100.00 | 100.00 | 100.00 | 100.00 | 100 | 100.0 | 100.00 |
| | LD-60(T1) | | | HD-60(T1) | | | UNWRAPPED (T) | | |
| 1 | - | - | - | - | - | - | - | - | - |
| 4 | - | - | - | - | - | - | - | - | - |
| 7 | - | - | - | - | - | - | 16.32 | 0 | 8.16 |
| 10 | - | - | - | - | - | - | 100 | 100 | 100.00 |
| 13 | 6.07 | 7.26 | 6.67 | 4.25 | 9.09 | 6.67 | | | |
| 16 | 24.45 | 21.67 | 23.06 | 28.23 | 18.29 | 23.26 | | | |
| 19 | 62.52 | 64.26 | 63.39 | 49.36 | 67.72 | 58.54 | | | |
| 22 | 100 | 100.00 | 100.00 | 100 | 100 | 100.00 | | | |
| | LD-60(T2) | | | HD-60(T2) | | | | | |
| 1 | - | - | - | - | - | - | | | |
| 4 | - | - | - | - | - | - | | | |
| 7 | - | - | - | - | - | - | | | |
| 10 | 4.38 | 7.88 | 6.13 | 0 | 10.62 | 5.31 | | | |
| 13 | 9.44 | 11.54 | 10.49 | 7.75 | 15.67 | 11.71 | | | |
| 16 | 19.25 | 28.29 | 23.77 | 18.5 | 29.42 | 23.96 | | | |
| 19 | 100 | 100 | 100.00 | 100 | 100 | 100.00 | | | |

| Storage period(day) | Treatments replications | | | | | | | | |
|--|-------------------------|--------|--------|-----------|-------|--------|----|----|------|
| | R1 | R2 | AVG. | R1 | R2 | AVG. | R1 | R2 | AVG. |
| | LD-60(T3) | | | HD-60(T3) | | | | | |
| 1 | - | - | - | - | - | - | | | |
| 4 | - | - | - | - | - | - | | | |
| 7 | 8.52 | 0.0 | 4.26 | 10.52 | 0 | 5.26 | | | |
| 10 | 10.96 | 15.7 | 13.33 | 17.28 | 13.84 | 15.56 | | | |
| 13 | 28.17 | 21.5 | 24.82 | 24.18 | 31.64 | 27.91 | | | |
| 16 | 100 | 100.0 | 100.00 | 100 | 100 | 100.00 | | | |
| | LD-80(T1) | | | HD-80(T1) | | | | | |
| 1 | - | - | - | - | - | - | | | |
| 4 | - | - | - | - | - | - | | | |
| 7 | - | - | - | - | - | - | | | |
| 10 | - | - | - | - | - | - | | | |
| 13 | 0 | 8.88 | 4.44 | - | - | - | | | |
| 16 | 8.39 | 14.87 | 11.63 | 9.3 | 0 | 4.65 | | | |
| 19 | 22.6 | 16.42 | 19.51 | 12.26 | 17 | 14.63 | | | |
| 22 | 61.25 | 85.00 | 73.13 | 100 | 100 | 100.00 | | | |
| 25 | 100 | 100.00 | 100.00 | | | | | | |
| | LD-80(T2) | | | HD-80(T2) | | | | | |
| 1 | - | - | - | - | - | - | | | |
| 4 | - | - | - | - | - | - | | | |
| 7 | - | - | - | - | - | - | | | |
| 10 | - | - | - | - | - | - | | | |
| 13 | 9.44 | 14.30 | 11.87 | 5.94 | 7.4 | 6.67 | | | |
| 16 | 11.09 | 16.82 | 13.95 | 18.91 | 28.07 | 23.49 | | | |
| 19 | 24.5 | 34.94 | 29.72 | 100 | 100 | 100.00 | | | |
| 22 | 100 | 100.00 | 100.00 | | | | | | |
| | LD-80(T3) | | | HD-80(T3) | | | | | |
| 1 | - | - | - | - | - | - | | | |
| 4 | - | - | - | - | - | - | | | |
| 7 | 0.00 | 11.6 | 5.78 | - | - | - | | | |
| 10 | 0.00 | 17.8 | 8.89 | 9.25 | 14.49 | 11.87 | | | |
| 13 | 18.0 | 19.24 | 18.60 | 29.92 | 25.9 | 27.91 | | | |
| 16 | 100.0 | 100 | 100.00 | 100 | 100 | 100.00 | | | |
| <p>* B & S and cold storage--no shrinkage No shrinkage in non- perforated treatments under room temperature storage</p> | | | | | | | | | |

APPENDIX - F

Table F1 TSS/acid ratio under room temperature storage conditions

| Storage Period (days) | ACIDITY | | | TSS | TSS/ACIDITY | | | |
|-----------------------|---------|------|------|-------|-------------|--------|--------|--------|
| | R1 | R2 | R3 | R1 | R1 | R2 | R3 | AVG. |
| Non-wrapped (T) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.21 | 1.22 | 1.21 | 7.40 | 6.07 | 6.07 | 6.14 | 6.09 |
| 7 | 0.56 | 0.56 | 0.56 | 16.80 | 29.85 | 29.85 | 29.85 | 29.85 |
| 10 | 0.13 | 0.13 | 0.13 | 12.00 | 89.55 | 89.55 | 89.55 | 89.55 |
| S-60 (T0) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.23 | 1.23 | 1.23 | 9.50 | 7.71 | 7.71 | 7.71 | 7.71 |
| 7 | 0.47 | 0.47 | 0.47 | 11.40 | 24.31 | 24.31 | 24.31 | 24.31 |
| 10 | 0.43 | 0.42 | 0.43 | 11.50 | 27.68 | 27.68 | 26.82 | 27.40 |
| 13 | 0.34 | 0.34 | 0.34 | 12.20 | 36.42 | 36.42 | 36.42 | 36.42 |
| 16 | 0.19 | 0.19 | 0.19 | 14.00 | 74.63 | 74.63 | 74.63 | 74.63 |
| 19 | 0.13 | 0.13 | 0.13 | 13.20 | 98.51 | 98.51 | 98.51 | 98.51 |
| 22 | 0.11 | 0.11 | 0.11 | 12.40 | 115.67 | 115.67 | 115.67 | 115.67 |
| S-60 (T4) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.46 | 1.45 | 1.46 | 10.00 | 6.91 | 6.91 | 6.85 | 6.89 |
| 7 | 0.42 | 0.40 | 0.42 | 11.50 | 28.61 | 28.61 | 27.68 | 28.30 |
| 10 | 0.31 | 0.31 | 0.31 | 12.50 | 40.56 | 40.56 | 40.56 | 40.56 |
| 13 | 0.25 | 0.25 | 0.24 | 13.50 | 53.02 | 53.02 | 55.97 | 54.01 |
| 16 | 0.15 | 0.15 | 0.15 | 13.00 | 88.20 | 88.20 | 88.20 | 88.20 |
| 19 | 0.12 | 0.12 | 0.12 | 11.70 | 97.01 | 97.01 | 97.01 | 97.01 |
| 22 | 0.09 | 0.09 | 0.08 | 11.20 | 119.40 | 119.40 | 139.30 | 126.04 |
| S-60 (T5) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.30 | 1.29 | 1.29 | 9.50 | 7.38 | 7.38 | 7.38 | 7.38 |
| 7 | 0.52 | 0.54 | 0.52 | 10.30 | 19.22 | 19.22 | 19.71 | 19.38 |
| 10 | 0.36 | 0.36 | 0.36 | 13.50 | 37.31 | 37.31 | 37.31 | 37.31 |
| 13 | 0.28 | 0.28 | 0.28 | 13.80 | 49.04 | 49.04 | 49.04 | 49.04 |
| 16 | 0.20 | 0.20 | 0.20 | 12.70 | 63.18 | 63.18 | 63.18 | 63.18 |
| 19 | 0.11 | 0.11 | 0.11 | 11.30 | 105.41 | 105.41 | 105.41 | 105.41 |
| 22 | 0.05 | 0.05 | 0.05 | 10.50 | 195.90 | 195.90 | 195.90 | 195.90 |
| LD-60 (T0) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.50 | 1.50 | 1.51 | 9.50 | 6.33 | 6.33 | 6.27 | 6.31 |
| 7 | 0.63 | 0.62 | 0.62 | 9.70 | 15.74 | 15.74 | 15.74 | 15.74 |
| 10 | 0.50 | 0.48 | 0.50 | 11.00 | 22.80 | 22.80 | 22.19 | 22.60 |
| 13 | 0.42 | 0.42 | 0.42 | 12.50 | 30.09 | 30.09 | 30.09 | 30.09 |
| 16 | 0.38 | 0.38 | 0.38 | 12.70 | 33.85 | 33.85 | 33.85 | 33.85 |
| 19 | 0.36 | 0.35 | 0.36 | 13.30 | 38.17 | 38.17 | 36.76 | 37.70 |
| 22 | 0.35 | 0.35 | 0.36 | 13.70 | 39.32 | 39.32 | 37.87 | 38.84 |

| t | R1 | R2 | R3 | R1 | R1 | R2 | R3 | AVG. |
|------------|------|------|------|-------|--------|--------|--------|--------|
| LD-60 (T4) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.41 | 1.41 | 1.42 | 10.90 | 7.75 | 7.75 | 7.67 | 7.72 |
| 7 | 0.84 | 0.84 | 0.84 | 11.80 | 13.98 | 13.98 | 13.98 | 13.98 |
| 10 | 0.44 | 0.44 | 0.44 | 12.50 | 28.27 | 28.27 | 28.27 | 28.27 |
| 13 | 0.31 | 0.31 | 0.32 | 13.30 | 43.15 | 43.15 | 41.36 | 42.55 |
| 16 | 0.25 | 0.24 | 0.25 | 13.40 | 55.56 | 55.56 | 52.63 | 54.58 |
| 19 | 0.20 | 0.20 | 0.20 | 12.60 | 62.69 | 62.69 | 62.69 | 62.69 |
| 22 | 0.08 | 0.08 | 0.08 | 10.50 | 130.60 | 130.60 | 130.60 | 130.60 |
| LD-60 (T5) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 0.96 | 0.95 | 0.96 | 9.50 | 9.99 | 9.99 | 9.85 | 9.94 |
| 7 | 0.83 | 0.83 | 0.83 | 12.20 | 14.68 | 14.68 | 14.68 | 14.68 |
| 10 | 0.43 | 0.42 | 0.43 | 13.25 | 31.90 | 31.90 | 30.90 | 31.56 |
| 13 | 0.17 | 0.17 | 0.17 | 14.30 | 82.09 | 82.09 | 82.09 | 82.09 |
| 16 | 0.12 | 0.12 | 0.12 | 12.10 | 100.33 | 100.33 | 100.33 | 100.33 |
| 19 | 0.07 | 0.07 | 0.07 | 10.50 | 156.72 | 156.72 | 156.72 | 156.72 |
| 22 | 0.05 | 0.05 | 0.05 | 10.00 | 186.57 | 186.57 | 186.57 | 186.57 |
| LD-80 (T0) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.03 | 1.02 | 1.02 | 9.00 | 8.84 | 8.84 | 8.84 | 8.84 |
| 7 | 0.59 | 0.59 | 0.59 | 10.70 | 18.15 | 18.15 | 18.15 | 18.15 |
| 10 | 0.52 | 0.52 | 0.52 | 12.50 | 23.92 | 23.92 | 23.92 | 23.92 |
| 13 | 0.42 | 0.42 | 0.42 | 13.00 | 31.30 | 31.30 | 31.30 | 31.30 |
| 16 | 0.40 | 0.40 | 0.40 | 13.50 | 33.58 | 33.58 | 33.58 | 33.58 |
| 19 | 0.29 | 0.29 | 0.29 | 13.75 | 46.64 | 46.64 | 46.64 | 46.64 |
| 22 | 0.21 | 0.21 | 0.21 | 13.30 | 62.03 | 62.03 | 62.03 | 62.03 |
| LD-80 (T4) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.25 | 1.23 | 1.23 | 10.50 | 8.52 | 8.52 | 8.52 | 8.52 |
| 7 | 0.83 | 0.83 | 0.83 | 12.50 | 15.05 | 15.05 | 15.05 | 15.05 |
| 10 | 0.42 | 0.42 | 0.42 | 12.90 | 31.05 | 31.05 | 31.05 | 31.05 |
| 13 | 0.28 | 0.28 | 0.28 | 14.10 | 50.11 | 50.11 | 50.11 | 50.11 |
| 16 | 0.24 | 0.24 | 0.24 | 14.40 | 59.70 | 59.70 | 59.70 | 59.70 |
| 19 | 0.20 | 0.20 | 0.20 | 14.20 | 70.65 | 70.65 | 70.65 | 70.65 |
| 22 | 0.15 | 0.15 | 0.15 | 13.70 | 92.94 | 92.94 | 92.94 | 92.94 |
| LD-80 (T5) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.09 | 1.07 | 1.07 | 10.50 | 9.79 | 9.79 | 9.79 | 9.79 |
| 7 | 0.42 | 0.40 | 0.42 | 12.50 | 31.09 | 31.09 | 30.09 | 30.76 |
| 10 | 0.28 | 0.27 | 0.27 | 13.20 | 49.25 | 49.25 | 49.25 | 49.25 |
| 13 | 0.21 | 0.21 | 0.21 | 13.50 | 62.97 | 62.97 | 62.97 | 62.97 |
| 16 | 0.13 | 0.13 | 0.12 | 14.20 | 105.97 | 105.97 | 117.74 | 109.89 |
| 19 | 0.09 | 0.09 | 0.08 | 11.20 | 119.40 | 119.40 | 139.30 | 126.04 |
| 22 | 0.08 | 0.08 | 0.08 | 11.10 | 138.06 | 138.06 | 138.06 | 138.06 |

Table F2 TSS/acid ratio under brick & sand storage conditions

| Storage Period (Days) | ACIDITY | | | TSS | TSS/ACIDITY | | | |
|-----------------------|---------|------|------|-------|-------------|--------|--------|--------|
| | R1 | R2 | R3 | R1 | R1 | R2 | R3 | AVG. |
| Non-wrapped (T) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.02 | 1.02 | 1.02 | 13.40 | 13.16 | 13.16 | 13.16 | 13.16 |
| 7 | 0.40 | 0.40 | 0.40 | 14.60 | 36.32 | 36.32 | 36.32 | 36.32 |
| 10 | 0.11 | 0.09 | 0.09 | 11.70 | 109.14 | 124.73 | 124.73 | 119.54 |
| S-60 (T0) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 0.76 | 0.75 | 0.75 | 11.30 | 14.79 | 15.06 | 15.06 | 14.97 |
| 7 | 0.54 | 0.54 | 0.54 | 11.50 | 21.46 | 21.46 | 21.46 | 21.46 |
| 10 | 0.40 | 0.40 | 0.42 | 12.70 | 31.59 | 31.59 | 30.57 | 31.25 |
| 13 | 0.24 | 0.24 | 0.24 | 13.00 | 53.90 | 53.90 | 53.90 | 53.90 |
| 16 | 0.20 | 0.20 | 0.20 | 14.10 | 70.15 | 70.15 | 70.15 | 70.15 |
| 19 | 0.17 | 0.17 | 0.17 | 12.60 | 72.33 | 72.33 | 72.33 | 72.33 |
| 22 | 0.12 | 0.12 | 0.12 | 11.80 | 97.84 | 97.84 | 97.84 | 97.84 |
| S-60 (T4) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.15 | 1.17 | 1.15 | 8.50 | 7.38 | 7.29 | 7.38 | 7.35 |
| 7 | 0.66 | 0.66 | 0.66 | 12.70 | 19.34 | 19.34 | 19.34 | 19.34 |
| 10 | 0.25 | 0.24 | 0.24 | 13.00 | 51.06 | 53.90 | 53.90 | 52.95 |
| 13 | 0.23 | 0.23 | 0.23 | 14.50 | 63.65 | 63.65 | 63.65 | 63.65 |
| 16 | 0.15 | 0.15 | 0.15 | 14.40 | 97.69 | 97.69 | 97.69 | 97.69 |
| 19 | 0.12 | 0.12 | 0.12 | 11.90 | 98.67 | 98.67 | 98.67 | 98.67 |
| 22 | 0.08 | 0.08 | 0.08 | 11.00 | 136.82 | 136.82 | 136.82 | 136.82 |
| S-60 (T5) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 0.82 | 0.83 | 0.83 | 9.30 | 11.38 | 11.19 | 11.19 | 11.26 |
| 7 | 0.51 | 0.52 | 0.51 | 11.70 | 22.98 | 22.39 | 22.98 | 22.78 |
| 10 | 0.48 | 0.48 | 0.48 | 12.00 | 24.88 | 24.88 | 24.88 | 24.88 |
| 13 | 0.21 | 0.21 | 0.23 | 13.25 | 61.80 | 61.80 | 58.17 | 60.59 |
| 16 | 0.19 | 0.19 | 0.19 | 13.60 | 72.49 | 72.49 | 72.49 | 72.49 |
| 19 | 0.11 | 0.11 | 0.11 | 11.30 | 105.41 | 105.41 | 105.41 | 105.41 |
| 22 | 0.07 | 0.07 | 0.07 | 10.80 | 161.19 | 161.19 | 161.19 | 161.19 |
| LD-60 (T0) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.21 | 1.21 | 1.21 | 7.90 | 6.55 | 6.55 | 6.55 | 6.55 |
| 7 | 0.79 | 0.78 | 0.79 | 11.80 | 14.93 | 15.18 | 14.93 | 15.01 |
| 10 | 0.46 | 0.46 | 0.46 | 12.50 | 27.44 | 27.44 | 27.44 | 27.44 |
| 13 | 0.35 | 0.35 | 0.35 | 12.60 | 36.17 | 36.17 | 36.17 | 36.17 |
| 16 | 0.27 | 0.27 | 0.27 | 14.35 | 53.54 | 53.54 | 53.54 | 53.54 |
| 19 | 0.23 | 0.23 | 0.23 | 12.60 | 55.31 | 55.31 | 55.31 | 55.31 |
| 22 | 0.20 | 0.20 | 0.20 | 12.30 | 61.19 | 61.19 | 61.19 | 61.19 |

| t | R1 | R2 | R3 | R1 | R1 | R2 | R3 | AVG. |
|------------|------|------|------|-------|--------|--------|--------|--------|
| LD-60 (T4) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.10 | 1.09 | 1.09 | 9.20 | 8.37 | 8.48 | 8.48 | 8.44 |
| 7 | 0.59 | 0.59 | 0.59 | 11.70 | 19.84 | 19.84 | 19.84 | 19.84 |
| 10 | 0.39 | 0.38 | 0.39 | 12.00 | 30.88 | 31.98 | 30.88 | 31.25 |
| 13 | 0.35 | 0.36 | 0.36 | 13.50 | 38.75 | 37.31 | 37.31 | 37.79 |
| 16 | 0.21 | 0.21 | 0.21 | 13.60 | 63.43 | 63.43 | 63.43 | 63.43 |
| 19 | 0.12 | 0.12 | 0.12 | 12.30 | 101.99 | 101.99 | 101.99 | 101.99 |
| 22 | 0.07 | 0.07 | 0.07 | 10.50 | 156.72 | 156.72 | 156.72 | 156.72 |
| LD-60 (T5) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 0.95 | 0.96 | 0.95 | 8.50 | 8.93 | 8.81 | 8.93 | 8.89 |
| 7 | 0.48 | 0.48 | 0.47 | 10.70 | 22.18 | 22.18 | 22.81 | 22.39 |
| 10 | 0.39 | 0.39 | 0.38 | 11.90 | 30.62 | 30.62 | 31.72 | 30.99 |
| 13 | 0.23 | 0.23 | 0.23 | 12.60 | 55.31 | 55.31 | 55.31 | 55.31 |
| 16 | 0.19 | 0.19 | 0.20 | 13.45 | 71.70 | 71.70 | 66.92 | 70.10 |
| 19 | 0.11 | 0.11 | 0.09 | 12.10 | 112.87 | 112.87 | 129.00 | 118.25 |
| 22 | 0.08 | 0.08 | 0.08 | 11.20 | 139.30 | 139.30 | 139.30 | 139.30 |
| LD-80 (T0) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.35 | 1.35 | 1.34 | 9.50 | 7.02 | 7.02 | 7.09 | 7.04 |
| 7 | 0.74 | 0.74 | 0.74 | 10.70 | 14.52 | 14.52 | 14.52 | 14.52 |
| 10 | 0.58 | 0.58 | 0.58 | 12.00 | 20.83 | 20.83 | 20.83 | 20.83 |
| 13 | 0.48 | 0.48 | 0.48 | 13.15 | 27.26 | 27.26 | 27.26 | 27.26 |
| 16 | 0.44 | 0.44 | 0.44 | 13.60 | 30.76 | 30.76 | 30.76 | 30.76 |
| 19 | 0.36 | 0.36 | 0.36 | 14.30 | 39.52 | 39.52 | 39.52 | 39.52 |
| 22 | 0.17 | 0.17 | 0.17 | 11.70 | 67.16 | 67.16 | 67.16 | 67.16 |
| LD-80 (T4) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.26 | 1.26 | 1.26 | 8.50 | 6.75 | 6.75 | 6.75 | 6.75 |
| 7 | 0.58 | 0.59 | 0.58 | 10.30 | 17.88 | 17.47 | 17.88 | 17.74 |
| 10 | 0.42 | 0.43 | 0.43 | 13.30 | 32.02 | 31.02 | 31.02 | 31.35 |
| 13 | 0.39 | 0.39 | 0.39 | 13.80 | 35.51 | 35.51 | 35.51 | 35.51 |
| 16 | 0.28 | 0.28 | 0.28 | 14.60 | 51.88 | 51.88 | 51.88 | 51.88 |
| 19 | 0.21 | 0.21 | 0.21 | 14.10 | 65.76 | 65.76 | 65.76 | 65.76 |
| 22 | 0.16 | 0.16 | 0.16 | 13.70 | 85.20 | 85.20 | 85.20 | 85.20 |
| LD-80 (T5) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.22 | 1.22 | 1.22 | 10.10 | 8.28 | 8.28 | 8.28 | 8.28 |
| 7 | 0.51 | 0.51 | 0.51 | 11.30 | 22.19 | 22.19 | 22.19 | 22.19 |
| 10 | 0.47 | 0.47 | 0.48 | 13.20 | 28.14 | 28.14 | 27.36 | 27.88 |
| 13 | 0.27 | 0.25 | 0.25 | 14.20 | 52.99 | 55.77 | 55.77 | 54.84 |
| 16 | 0.17 | 0.17 | 0.16 | 14.20 | 81.52 | 81.52 | 88.31 | 83.78 |
| 19 | 0.12 | 0.12 | 0.12 | 13.45 | 111.53 | 111.53 | 111.53 | 111.53 |
| 22 | 0.09 | 0.09 | 0.11 | 11.10 | 118.34 | 118.34 | 103.54 | 113.41 |

Table F3 TSS/acid ratio under cold storage conditions

| Storage Period (Days) | ACIDITY | | | TSS | TSS/ACIDITY | | | | |
|-----------------------|---------|------|------|-------|-------------|-------|-------|-------|--|
| | R1 | R2 | R3 | R1 | R1 | R2 | R3 | AVG. | |
| Non-wrapped (T) | | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 | |
| 4 | 1.47 | 1.47 | 1.47 | 9.80 | 6.65 | 6.65 | 6.65 | 6.65 | |
| 7 | 1.41 | 1.41 | 1.41 | 11.50 | 8.17 | 8.17 | 8.17 | 8.17 | |
| 10 | 1.15 | 1.15 | 1.15 | 11.60 | 10.07 | 10.07 | 10.07 | 10.07 | |
| 13 | 0.94 | 0.94 | 0.92 | 10.80 | 11.51 | 11.51 | 11.68 | 11.57 | |
| 16 | 0.59 | 0.59 | 0.59 | 16.80 | 28.49 | 28.49 | 28.49 | 28.49 | |
| 19 | 0.56 | 0.56 | 0.56 | 15.80 | 28.07 | 28.07 | 28.07 | 28.07 | |
| 22 | 0.44 | 0.44 | 0.44 | 10.80 | 24.42 | 24.42 | 24.42 | 24.42 | |
| S-60 (T0) | | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 | |
| 4 | 1.41 | 1.39 | 1.39 | 8.50 | 6.04 | 6.10 | 6.10 | 6.08 | |
| 7 | 1.09 | 1.09 | 1.09 | 9.50 | 8.75 | 8.75 | 8.75 | 8.75 | |
| 10 | 0.82 | 0.82 | 0.83 | 11.30 | 13.82 | 13.82 | 13.60 | 13.75 | |
| 13 | 0.71 | 0.70 | 0.71 | 11.60 | 16.33 | 16.65 | 16.33 | 16.44 | |
| 16 | 0.58 | 0.58 | 0.58 | 12.20 | 21.17 | 21.17 | 21.17 | 21.17 | |
| 19 | 0.38 | 0.38 | 0.38 | 12.50 | 33.32 | 33.32 | 33.32 | 33.32 | |
| 22 | 0.31 | 0.31 | 0.31 | 12.80 | 41.53 | 41.53 | 41.53 | 41.53 | |
| 25 | 0.24 | 0.24 | 0.24 | 12.90 | 53.48 | 53.48 | 53.48 | 53.48 | |
| 28 | 0.21 | 0.21 | 0.21 | 15.20 | 70.90 | 70.90 | 70.90 | 70.90 | |
| S-60 (T4) | | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 | |
| 4 | 1.21 | 1.21 | 1.21 | 10.50 | 8.71 | 8.71 | 8.71 | 8.71 | |
| 7 | 0.84 | 0.84 | 0.84 | 11.90 | 14.10 | 14.10 | 14.10 | 14.10 | |
| 10 | 0.60 | 0.60 | 0.60 | 12.50 | 20.73 | 20.73 | 20.73 | 20.73 | |
| 13 | 0.52 | 0.52 | 0.52 | 12.70 | 24.30 | 24.30 | 24.30 | 24.30 | |
| 16 | 0.50 | 0.50 | 0.50 | 14.50 | 29.25 | 29.25 | 29.25 | 29.25 | |
| 19 | 0.24 | 0.24 | 0.24 | 12.40 | 51.41 | 51.41 | 51.41 | 51.41 | |
| 22 | 0.21 | 0.21 | 0.21 | 12.20 | 56.90 | 56.90 | 56.90 | 56.90 | |
| 25 | 0.16 | 0.16 | 0.16 | 11.30 | 70.27 | 70.27 | 70.27 | 70.27 | |
| 28 | 0.13 | 0.13 | 0.13 | 10.90 | 81.34 | 81.34 | 81.34 | 81.34 | |
| S-60 (T5) | | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 | |
| 4 | 1.22 | 1.22 | 1.22 | 10.70 | 8.77 | 8.77 | 8.77 | 8.77 | |
| 7 | 0.90 | 0.90 | 0.91 | 11.50 | 12.81 | 12.81 | 12.62 | 12.75 | |
| 10 | 0.62 | 0.60 | 0.60 | 11.70 | 18.98 | 19.40 | 19.40 | 19.26 | |
| 13 | 0.52 | 0.52 | 0.52 | 12.50 | 23.92 | 23.92 | 23.92 | 23.92 | |
| 16 | 0.51 | 0.51 | 0.51 | 12.90 | 25.33 | 25.33 | 25.33 | 25.33 | |
| 19 | 0.39 | 0.39 | 0.39 | 13.00 | 33.45 | 33.45 | 33.45 | 33.45 | |
| 22 | 0.25 | 0.25 | 0.25 | 12.70 | 49.88 | 49.88 | 49.88 | 49.88 | |
| 25 | 0.15 | 0.15 | 0.15 | 10.70 | 72.59 | 72.59 | 72.59 | 72.59 | |
| 28 | 0.11 | 0.11 | 0.11 | 10.40 | 97.01 | 97.01 | 97.01 | 97.01 | |
| LD-60 (T0) | | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 | |
| 4 | 1.23 | 1.23 | 1.23 | 9.60 | 7.79 | 7.79 | 7.79 | 7.79 | |
| 7 | 1.14 | 1.14 | 1.14 | 10.00 | 8.78 | 8.78 | 8.78 | 8.78 | |
| 10 | 1.03 | 1.03 | 1.03 | 10.10 | 9.79 | 9.79 | 9.79 | 9.79 | |
| 13 | 0.64 | 0.64 | 0.64 | 12.10 | 18.81 | 18.81 | 18.81 | 18.81 | |
| 16 | 0.58 | 0.58 | 0.58 | 12.20 | 21.17 | 21.17 | 21.17 | 21.17 | |
| 19 | 0.52 | 0.52 | 0.52 | 12.70 | 24.30 | 24.30 | 24.30 | 24.30 | |
| 22 | 0.52 | 0.52 | 0.52 | 13.80 | 26.41 | 26.41 | 26.41 | 26.41 | |
| 25 | 0.47 | 0.47 | 0.47 | 12.50 | 26.65 | 26.65 | 26.65 | 26.65 | |
| 28 | 0.38 | 0.38 | 0.38 | 12.40 | 33.05 | 33.05 | 33.05 | 33.05 | |

| t | R1 | R2 | R3 | R1 | R1 | R2 | R3 | AVG. |
|------------|------|------|------|-------|--------|--------|--------|--------|
| LD-60 (T4) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.13 | 1.13 | 1.13 | 8.60 | 7.64 | 7.64 | 7.64 | 7.64 |
| 7 | 1.09 | 1.09 | 1.09 | 10.50 | 9.67 | 9.67 | 9.67 | 9.67 |
| 10 | 1.05 | 1.05 | 1.05 | 10.70 | 10.24 | 10.24 | 10.24 | 10.24 |
| 13 | 0.82 | 0.82 | 0.82 | 11.90 | 14.56 | 14.56 | 14.56 | 14.56 |
| 16 | 0.51 | 0.51 | 0.51 | 12.90 | 25.33 | 25.33 | 25.33 | 25.33 |
| 19 | 0.48 | 0.48 | 0.48 | 13.00 | 26.95 | 26.95 | 26.95 | 26.95 |
| 22 | 0.35 | 0.35 | 0.35 | 14.70 | 42.19 | 42.19 | 42.19 | 42.19 |
| 25 | 0.28 | 0.28 | 0.28 | 12.20 | 43.35 | 43.35 | 43.35 | 43.35 |
| 28 | 0.13 | 0.13 | 0.13 | 9.40 | 70.15 | 70.15 | 70.15 | 70.15 |
| LD-60 (T5) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.27 | 1.26 | 1.26 | 10.50 | 8.25 | 8.34 | 8.34 | 8.31 |
| 7 | 1.03 | 1.03 | 1.03 | 10.60 | 10.27 | 10.27 | 10.27 | 10.27 |
| 10 | 0.88 | 0.88 | 0.88 | 11.70 | 13.23 | 13.23 | 13.23 | 13.23 |
| 13 | 0.64 | 0.64 | 0.64 | 12.00 | 18.66 | 18.66 | 18.66 | 18.66 |
| 16 | 0.35 | 0.35 | 0.35 | 12.50 | 35.88 | 35.88 | 35.88 | 35.88 |
| 19 | 0.31 | 0.31 | 0.31 | 13.20 | 42.83 | 42.83 | 42.83 | 42.83 |
| 22 | 0.15 | 0.15 | 0.15 | 13.20 | 89.55 | 89.55 | 89.55 | 89.55 |
| 25 | 0.12 | 0.12 | 0.12 | 12.70 | 105.31 | 105.31 | 105.31 | 105.31 |
| 28 | 0.07 | 0.07 | 0.07 | 10.90 | 162.69 | 162.69 | 162.69 | 162.69 |
| LD-80 (T0) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.29 | 1.29 | 1.29 | 9.30 | 7.23 | 7.23 | 7.23 | 7.23 |
| 7 | 1.03 | 1.02 | 1.02 | 9.70 | 9.40 | 9.52 | 9.52 | 9.48 |
| 10 | 0.83 | 0.83 | 0.83 | 10.30 | 12.40 | 12.40 | 12.40 | 12.40 |
| 13 | 0.82 | 0.82 | 0.82 | 10.50 | 12.85 | 12.85 | 12.85 | 12.85 |
| 16 | 0.75 | 0.75 | 0.75 | 10.60 | 14.13 | 14.13 | 14.13 | 14.13 |
| 19 | 0.56 | 0.56 | 0.56 | 11.20 | 19.90 | 19.90 | 19.90 | 19.90 |
| 22 | 0.52 | 0.52 | 0.52 | 11.70 | 22.39 | 22.39 | 22.39 | 22.39 |
| 25 | 0.48 | 0.48 | 0.48 | 11.80 | 24.46 | 24.46 | 24.46 | 24.46 |
| 28 | 0.42 | 0.42 | 0.42 | 14.30 | 34.42 | 34.42 | 34.42 | 34.42 |
| LD-80 (T4) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.22 | 1.22 | 1.22 | 9.70 | 7.95 | 7.95 | 7.95 | 7.95 |
| 7 | 1.11 | 1.11 | 1.11 | 10.50 | 9.44 | 9.44 | 9.44 | 9.44 |
| 10 | 1.07 | 1.07 | 1.09 | 11.50 | 10.73 | 10.73 | 10.60 | 10.68 |
| 13 | 1.05 | 1.05 | 1.05 | 11.80 | 11.29 | 11.29 | 11.29 | 11.29 |
| 16 | 0.54 | 0.54 | 0.54 | 12.40 | 23.13 | 23.13 | 23.13 | 23.13 |
| 19 | 0.43 | 0.43 | 0.43 | 13.70 | 31.95 | 31.95 | 31.95 | 31.95 |
| 22 | 0.35 | 0.35 | 0.35 | 13.40 | 38.46 | 38.46 | 38.46 | 38.46 |
| 25 | 0.28 | 0.28 | 0.28 | 12.90 | 45.84 | 45.84 | 45.84 | 45.84 |
| 28 | 0.24 | 0.24 | 0.24 | 12.20 | 50.58 | 50.58 | 50.58 | 50.58 |
| LD-80 (T5) | | | | | | | | |
| 1 | 1.61 | 1.61 | 1.61 | 6.40 | 3.98 | 3.98 | 3.98 | 3.98 |
| 4 | 1.30 | 1.29 | 1.29 | 8.70 | 6.69 | 6.76 | 6.76 | 6.74 |
| 7 | 0.95 | 0.96 | 0.95 | 10.30 | 10.83 | 10.68 | 10.83 | 10.78 |
| 10 | 0.92 | 0.92 | 0.92 | 11.10 | 12.01 | 12.01 | 12.01 | 12.01 |
| 13 | 0.60 | 0.60 | 0.60 | 11.50 | 19.07 | 19.07 | 19.07 | 19.07 |
| 16 | 0.39 | 0.39 | 0.39 | 12.40 | 31.91 | 31.91 | 31.91 | 31.91 |
| 19 | 0.20 | 0.20 | 0.20 | 13.00 | 64.68 | 64.68 | 64.68 | 64.68 |
| 22 | 0.16 | 0.16 | 0.16 | 13.90 | 86.44 | 86.44 | 86.44 | 86.44 |
| 25 | 0.13 | 0.13 | 0.13 | 13.20 | 98.51 | 98.51 | 98.51 | 98.51 |
| 28 | 0.09 | 0.09 | 0.09 | 11.20 | 119.40 | 119.40 | 119.40 | 119.40 |

APPENDIX - G

Table G1 Respiration rate data based upon O₂ consumption and CO₂ evolution

| Time (days) | Oxygen (%) | | | Time (days) | Carbondioxide (%) | | |
|-------------|------------|-------|-------|-------------|-------------------|-------|-------|
| | R1 | R2 | AVG. | | R1 | R2 | AVG. |
| t | | | | t | | | |
| 0.00 | 21.00 | 21.00 | 21.00 | 0.00 | 0.03 | 0.03 | 0.03 |
| 3.90 | 5.88 | 8.40 | 7.14 | 4.53 | 1.71 | 2.01 | 1.86 |
| 7.92 | 4.47 | 3.05 | 3.76 | 8.67 | 5.31 | 4.71 | 5.01 |
| 11.10 | 3.17 | 2.43 | 2.80 | 12.03 | 6.85 | 6.35 | 6.6 |
| 18.77 | 2.31 | 1.15 | 1.73 | 18.47 | 10.47 | 9.47 | 9.97 |
| 22.73 | 2.09 | 1.37 | 1.73 | 23.11 | 12.23 | 11.51 | 11.87 |
| 29.85 | 1.99 | 1.47 | 1.73 | 26.91 | 14.56 | 13.94 | 14.25 |
| 33.75 | 1.99 | 1.47 | 1.73 | 31.51 | 21.05 | 21.41 | 21.23 |
| | | | | 34.46 | 20.98 | 20.70 | 20.84 |
| | | | | 37.73 | 21.03 | 20.85 | 20.94 |

Table G2 Experimental data of permeability studies on LD-80 film

| Time(hrs) | R1 | R2 | AVG | Time(hrs) | R1 | R2 | AVG |
|---------------------------|-------|-------|-------|--------------------------|-------|-------|-------|
| Gas permeability | | | | | | | |
| Oxygen(%) | | | | Carbondioxide (%) | | | |
| 0.00 | 1.57 | 1.57 | 1.57 | 0.00 | 21.50 | 21.50 | 21.50 |
| 6.68 | 3.10 | 3.20 | 3.15 | 8.55 | 5.86 | 5.68 | 5.77 |
| 27.21 | 5.66 | 6.70 | 6.18 | 15.13 | 4.28 | 4.40 | 4.34 |
| 50.38 | 7.95 | 7.62 | 7.79 | 25.52 | 3.72 | 4.06 | 3.89 |
| 74.08 | 9.77 | 9.65 | 9.71 | 32.07 | 3.29 | 2.98 | 3.13 |
| 79.89 | 10.81 | 12.19 | 11.50 | 52.25 | 2.20 | 2.84 | 2.52 |
| 98.08 | 12.77 | 13.64 | 13.21 | 75.82 | 1.62 | 1.55 | 1.58 |
| 122.12 | 15.56 | 14.56 | 15.06 | 99.48 | 1.25 | 1.43 | 1.34 |
| 146.40 | 16.55 | 17.32 | 16.94 | 105.60 | 1.00 | 0.90 | 0.95 |
| 169.92 | 19.13 | 18.92 | 19.03 | 123.50 | 0.03 | 0.03 | 0.03 |
| 195.4 | 20.22 | 21.45 | 20.84 | 133.50 | 0.03 | 0.03 | 0.03 |
| 220.16 | 20.80 | 20.88 | 20.84 | | | | |
| 231.50 | 20.74 | 20.94 | 20.84 | | | | |
| Water vapour (gms) | | | | | | | |
| 0 | 0.00 | 0.00 | 0.00 | | | | |
| 49 | 0.45 | 0.43 | 0.44 | | | | |
| 96 | 0.81 | 0.77 | 0.79 | | | | |
| 145.5 | 1.10 | 1.04 | 1.07 | | | | |
| 197 | 1.49 | 1.42 | 1.46 | | | | |
| 241 | 1.84 | 1.77 | 1.81 | | | | |
| 289 | 2.30 | 2.21 | 2.26 | | | | |
| 336 | 2.79 | 2.75 | 2.77 | | | | |
| 384 | 3.22 | 3.08 | 3.15 | | | | |

Table G3 Experimental data on gas exchange (O₂,CO₂) in different films

| Time (Days) | Number of perforations | | | | | | | | |
|--------------------------|------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| | N=0 | | | N=2 | | | N=4 | | |
| | R1 | R2 | AVG. | R1 | R2 | AVG. | R1 | R2 | AVG. |
| OXYGEN (%) | | | | | | | | | |
| LD-80 | | | | | | | | | |
| 0.00 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 | 21 |
| 1.00 | 6.01 | 6.69 | 6.35 | 5.91 | 6.07 | 5.99 | 6.67 | 6.95 | 6.81 |
| 2.00 | 4.86 | 5.36 | 5.11 | 6.51 | 6.37 | 6.44 | 7.29 | 7.53 | 7.41 |
| 3.00 | 4.38 | 4.68 | 4.53 | 6.82 | 6.64 | 6.73 | 7.53 | 7.61 | 7.57 |
| 4.00 | 4.21 | 4.43 | 4.32 | 6.84 | 6.9 | 6.87 | 7.84 | 7.50 | 7.67 |
| 5.79 | 3.94 | 4.28 | 4.11 | 6.74 | 6.82 | 6.78 | 7.56 | 7.50 | 7.53 |
| 8.44 | 3.73 | 3.99 | 3.86 | | | | | | |
| 13.39 | 2.85 | 3.03 | 2.94 | | | | | | |
| 18.45 | 2.63 | 2.79 | 2.71 | | | | | | |
| 21.33 | 2.6 | 2.76 | 2.68 | | | | | | |
| 25.76 | 2.59 | 2.75 | 2.67 | | | | | | |
| 30.89 | 2.48 | 2.34 | 2.41 | | | | | | |
| 34.50 | 2.56 | 2.72 | 2.64 | | | | | | |
| 39.63 | 2.59 | 2.75 | 2.67 | | | | | | |
| 41.05 | 2.69 | 2.57 | 2.63 | | | | | | |
| 43.26 | 2.78 | 2.6 | 2.69 | | | | | | |
| S--60 | | | | | | | | | |
| 0.00 | 21.00 | 21.00 | 21.00 | 21.00 | 21.00 | 21.00 | 21.00 | 21.00 | 21.00 |
| 1.11 | 6.14 | 6 | 6.07 | 6.45 | 6.15 | 6.30 | 6.54 | 6.82 | 6.68 |
| 2.1 | 5.05 | 5.01 | 5.03 | 6.69 | 6.49 | 6.59 | 7.57 | 7.35 | 7.46 |
| 3.14 | 4.81 | 4.41 | 4.61 | 6.46 | 6.70 | 6.58 | 7.42 | 7.70 | 7.56 |
| 4.23 | 4.3 | 4.02 | 4.16 | 6.56 | 6.82 | 6.69 | 7.57 | 7.41 | 7.49 |
| 5.9 | 3.49 | 3.99 | 3.74 | 6.70 | 6.40 | 6.55 | 7.53 | 7.59 | 7.56 |
| 8.55 | 3.34 | 3.54 | 3.44 | | | | | | |
| 13.58 | 2.79 | 2.99 | 2.89 | | | | | | |
| 18.56 | 2.79 | 2.53 | 2.66 | | | | | | |
| 21.52 | 2.71 | 2.51 | 2.61 | | | | | | |
| 25.88 | 2.47 | 2.51 | 2.49 | | | | | | |
| 31.04 | 2.29 | 2.37 | 2.33 | | | | | | |
| 35.48 | 2.38 | 2.44 | 2.41 | | | | | | |
| 39.81 | 2.31 | 2.43 | 2.37 | | | | | | |
| 43.93 | 2.23 | 2.35 | 2.29 | | | | | | |
| 48.77 | 2.35 | 2.31 | 2.33 | | | | | | |
| Carbondioxide (%) | | | | | | | | | |
| LD-80 | | | | | | | | | |
| 0.00 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 5.79 | 1.98 | 2.70 | 2.34 | 1.89 | 2.13 | 2.01 | 1.27 | 1.39 | 1.33 |
| 8.44 | 3.06 | 3.46 | 3.26 | 2.92 | 2.16 | 2.54 | 1.94 | 2.42 | 2.18 |
| 13.39 | 5.26 | 5.37 | 5.32 | 3.59 | 2.95 | 3.27 | 2.23 | 2.85 | 2.54 |
| 18.45 | 7.19 | 8.88 | 8.04 | 4.26 | 4.74 | 4.50 | 3.28 | 2.72 | 3.00 |
| 25.76 | 9.89 | 10.70 | 10.30 | 4.87 | 5.29 | 5.08 | 3.82 | 3.02 | 3.42 |
| 30.89 | 11.68 | 12.67 | 12.18 | 5.28 | 6.04 | 5.66 | 4.33 | 3.68 | 4.01 |
| 34.50 | 13.81 | 13.61 | 13.71 | 5.96 | 6.56 | 6.26 | 4.46 | 3.94 | 4.20 |
| 39.63 | 15.47 | 14.12 | 14.80 | 6.46 | 6.71 | 6.59 | 4.17 | 4.19 | 4.18 |
| 43.46 | 15.97 | 15.36 | 15.67 | 6.39 | 6.68 | 6.54 | 4.12 | 4.18 | 4.15 |
| 48.63 | 14.92 | 16.06 | 15.49 | 6.38 | 6.80 | 6.59 | 4.37 | 4.17 | 4.27 |
| 52.10 | 15.43 | 15.83 | 15.63 | 6.76 | 6.56 | 6.66 | 4.09 | 4.27 | 4.18 |
| 56.23 | 15.51 | 15.79 | 15.65 | | | | | | |

APPENDIX-H

Table H1 ANALYSIS OF RANDOMISED BLOCK DESIGN (RBD)

PLW (10)

NR = 2 NT = 13 NE = 1
 Analysis of RBD

| | | TREATMENT MEANS | | | | |
|----|-----------|-------------------|-----------|-----------|-----------|--|
| 1 | 12.745000 | 2.6500000 | 8.0300000 | 8.7000000 | 9.4800000 | |
| 6 | 1.7550000 | 7.8150000 | 8.1350000 | 8.9650000 | 2.2500000 | |
| 11 | 8.0150000 | 8.2850000 | 10.075000 | | | |
| | | REPLICATION MEANS | | | | |
| 1 | 10.048460 | 4.8592310 | | | | |

| ANOVA TABLE | | | | | | |
|-------------|------|-----------|---------|---------|-----------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | G.M. | C.V. |
| Replicates | 1 | 175.03260 | 50.88 | 1.58554 | | |
| Treatments | 12 | 21.229060 | 6.17 | 4.04235 | | |
| Error | 12 | 3.4401320 | | | 7.4538460 | 24.88 |

FIRMNESS (10)

NR = 2 NT = 13 NE = 1
 Analysis of RBD

| | | TREATMENT MEANS | | | | |
|----|-----------|-------------------|-----------|-----------|-----------|--|
| 1 | 5.0800000 | 8.6849990 | 5.7700000 | 5.8850000 | 6.5200000 | |
| 6 | 11.115000 | 5.4000000 | 5.9000000 | 6.6850000 | 5.3350000 | |
| 11 | 4.8150000 | 5.0000000 | 6.1200000 | | | |
| | | REPLICATION MEANS | | | | |
| 1 | 5.9546160 | 6.7084610 | | | | |

| ANOVA TABLE | | | | | | |
|-------------|------|-----------|---------|---------|-----------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | G.M. | C.V. |
| Replicates | 1 | 3.6937630 | 3.29 | NS | | |
| Treatments | 12 | 6.1377360 | 5.46 | 2.30977 | | |
| Error | 12 | 1.1231660 | | | 6.3315390 | 16.74 |

TSS (10)

NR = 2 NT = 13 NE = 1
 Analysis of RBD

| | | TREATMENT MEANS | | | | |
|----|-----------|-------------------|-----------|-----------|-----------|--|
| 1 | 17.100000 | 17.000000 | 18.850000 | 17.500000 | 19.000000 | |
| 6 | 16.050000 | 16.500000 | 16.000000 | 17.200000 | 16.900000 | |
| 11 | 17.650000 | 18.750000 | 17.050000 | | | |
| | | REPLICATION MEANS | | | | |
| 1 | 17.676920 | 17.023080 | | | | |

| ANOVA TABLE | | | | | | |
|-------------|------|-----------|---------|--------|-----------|------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | G.M. | C.V. |
| Replicates | 1 | 2.7801980 | 1.09 | NS | | |
| Treatments | 12 | 1.9634200 | .77 | NS | | |
| Error | 12 | 2.5537170 | | | 17.350000 | 9.21 |

ROTTING (10)

NR = 2 NT = 13 NE = 1
 Analysis of RBD

| TREATMENT MEANS | | | | | |
|-----------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 54.250000 | .00000000 | .00000000 | .00000000 | 1.5450000 |
| 6 | .00000000 | .00000000 | .00000000 | .00000000 | .00000000 |

pH VALUE (10)

NR = 2 NT = 13 NE = 1
 Analysis of RBD

| TREATMENT MEANS | | | | | |
|-------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 5.4800000 | 5.0100000 | 5.0100000 | 5.0600000 | 5.2350000 |
| 6 | 4.0150000 | 5.0250000 | 5.1450000 | 5.0700000 | 5.0050000 |
| 11 | 5.2750000 | 5.3000000 | 5.2500000 | | |
| REPLICATION MEANS | | | | | |
| 1 | 5.1076930 | 5.0276920 | | | |

| ANOVA TABLE | | | | | | |
|-------------|------|---------------|---------|---------|-----------|------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | G.M. | C.V. |
| Replicates | 1 | .41701100E-01 | 2.38 | NS | | |
| Treatments | 12 | .24246720 | 13.82 | .288654 | | |
| Error | 12 | .17541350E-01 | | | 5.0676920 | 2.61 |

TSS-ACIDITY-10

NR = 3 NT = 10 NE = 1
 Analysis of RBD

| TREATMENT MEANS | | | | | |
|-------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 73.053340 | 19.943330 | 23.253330 | 25.260000 | 17.900000 |
| 6 | 24.360000 | 29.713330 | 24.133330 | 38.080000 | 27.150000 |
| REPLICATION MEANS | | | | | |
| 1 | 37.802000 | 39.836000 | 13.216000 | | |

| ANOVA TABLE | | | | | | |
|-------------|------|-----------|---------|---------|-----------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | G.M. | C.V. |
| Replicates | 2 | 2195.3900 | 8.70 | 14.9217 | | |
| Treatments | 9 | 769.34330 | 3.05 | 27.2432 | | |
| Error | 18 | 252.44600 | | | 30.284670 | 52.46 |

Table H2 ANALYSIS OF FACTORIAL IN RANDOMISED BLOCK DESIGN (FRBD)

PLW (10)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|------------|-----------|-----------|-----------|
| 1 | 2.6500000 | 8.0300000 | 8.7000000 | 9.4800000 | 1.7550000 |
| 6 | 7.8150000 | 8.1350000 | 8.9650000 | 2.2500000 | 8.0150000 |
| 11 | 8.2850000 | 10.0750000 | | | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|-----------|--|
| 1 | 7.2150000 | 6.6675000 | 7.1562500 | | |
| 2 | 2.2183330 | 7.9533330 | 8.3733330 | 9.5066670 | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 145.77990 | 44.54 | | |
| A | 2 | .72271730 | .22 | NS | |
| B | 3 | 63.883830 | 19.52 | 2.29802 | |
| AB | 6 | .16550700 | .05 | NS | |
| Error | 11 | 3.2732710 | | | 25.80 |

FIRMNESS (10)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 8.6849990 | 5.7700000 | 6.1150000 | 6.5200000 | 11.115000 |
| 6 | 5.4000000 | 5.9000000 | 6.6850000 | 5.3350000 | 4.8150000 |
| 11 | 5.0000000 | 6.1200000 | | | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|-----------|--|
| 1 | 6.7725000 | 7.2750000 | 5.3175000 | | |
| 2 | 8.3783330 | 5.3283330 | 5.6716670 | 6.4416670 | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 4.1333620 | 3.40 | | |
| A | 2 | 8.2683720 | 6.81 | 1.21233 | |
| B | 3 | 11.164710 | 9.19 | 1.39988 | |
| AB | 6 | 3.3030730 | 2.72 | NS | |
| Error | 11 | 1.2146610 | | | 17.07 |

TSS (10)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 17.000000 | 18.850000 | 17.500000 | 19.000000 | 16.050000 |
| 6 | 16.500000 | 16.000000 | 17.200000 | 16.900000 | 17.650000 |
| 11 | 18.750000 | 17.050000 | | | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|-----------|--|
| 1 | 18.087500 | 16.437500 | 17.587500 | | |
| 2 | 16.650000 | 17.666670 | 17.416670 | 17.750000 | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|--------|------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 3.4514970 | 1.27 | | |
| A | 2 | 5.7270510 | 2.11 | NS | |
| B | 3 | 1.5061850 | .56 | NS | |
| AB | 6 | 1.2421060 | .46 | NS | |
| Error | 11 | 2.7085110 | | | 9.47 |

ROTTING (10)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | .00000000 | .00000000 | .00000000 | 4.1000000 | .00000000 |
| 6 | .00000000 | .00000000 | .00000000 | .00000000 | .00000000 |
| 11 | .00000000 | 6.3150000 | | | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|-----------|--|
| 1 | 1.0250000 | .00000000 | 1.5787500 | | |
| 2 | .00000000 | .00000000 | .00000000 | 3.4716670 | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|--------|--------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 8.9426030 | 1.35 | | |
| A | 2 | 5.1329550 | .77 | NS | |
| B | 3 | 18.078700 | 2.73 | NS | |
| AB | 6 | 5.1329540 | .77 | NS | |
| Error | 11 | 6.6232770 | | | 296.52 |

pH (10)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 5.0100000 | 5.0100000 | 5.0600000 | 5.2350000 | 4.0150000 |
| 6 | 5.0250000 | 5.1450000 | 5.0700000 | 5.0050000 | 5.2750000 |
| 11 | 5.3000000 | 5.2500000 | | | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|-----------|--|
| 1 | 5.0787500 | 4.8137500 | 5.2075000 | | |
| 2 | 4.6766670 | 5.1033330 | 5.1683340 | 5.1850000 | |

| ANOVA TABLE | | | | | |
|-------------|------|---------------|---------|---------|------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | .58044430E-01 | 3.47 | | |
| A | 2 | .32244870 | 19.25 | .142370 | |
| B | 3 | .34665930 | 20.69 | .164395 | |
| AB | 6 | .14273070 | 8.52 | .284740 | |
| Error | 11 | .16751380E-01 | | | 2.57 |

PLW (16)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 4.3000000 | 12.930000 | 14.120000 | 15.035000 | 3.1100000 |
| 6 | 12.555000 | 13.065000 | 14.640000 | 3.5200000 | 13.155000 |
| 11 | 13.510000 | 15.005000 | | | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|-----------|--|
| 1 | 11.596250 | 10.842500 | 11.297500 | | |
| 2 | 3.6433330 | 12.880000 | 13.565000 | 14.893330 | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 358.13110 | 47.65 | | |
| A | 2 | 1.1527100 | .15 | NS | |
| B | 3 | 158.30270 | 21.06 | 3.48203 | |
| AB | 6 | .13994850 | .02 | NS | |
| Error | 11 | 7.5152030 | | | 24.38 |

FIRMNESS (16)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 5.6000000 | 5.2500000 | 5.1650000 | 5.3500000 | 7.7000000 |
| 6 | 4.5800000 | 4.9500000 | 5.1350000 | 4.7150000 | 3.6500000 |
| 11 | 3.9850000 | 3.9000000 | | | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|-----------|--|
| 1 | 5.3412500 | 5.5912500 | 4.0625000 | | |
| 2 | 6.0050000 | 4.4933330 | 4.7000000 | 4.7950000 | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 5.1337080 | 10.81 | | |
| A | 2 | 5.3797000 | 11.33 | .757936 | |
| B | 3 | 2.7974850 | 5.89 | .875190 | |
| AB | 6 | .87577310 | 1.84 | NS | |
| Error | 11 | .47476660 | | | 13.79 |

TSS (16)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 16.200000 | 13.450000 | 14.800000 | 14.550000 | 18.600000 |
| 6 | 14.100000 | 14.500000 | 14.400000 | 14.400000 | 14.250000 |
| 11 | 15.800000 | 14.700000 | | | |
| FACTOR MEANS | | | | | |
| 1 | 14.750000 | 15.400000 | 14.787500 | | |
| 2 | 16.400000 | 13.933330 | 15.033330 | 14.550000 | |
| ANOVA TABLE | | | | | |
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 4.5934240 | 2.85 | | |
| A | 2 | 1.0651860 | .66 | NS | |
| B | 3 | 6.5992840 | 4.10 | 1.61128 | |
| AB | 6 | 3.0493980 | 1.89 | NS | |
| Error | 11 | 1.6092270 | | | 8.47 |

ROTTING (6)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 3.2200000 | 12.505000 | 9.1400000 | 20.715000 | 1.5050000 |
| 6 | 2.1050000 | 13.415000 | 16.645000 | 13.125000 | 57.240000 |
| 11 | 74.505000 | 63.175000 | | | |
| FACTOR MEANS | | | | | |
| 1 | 11.395000 | 8.4175000 | 52.011250 | | |
| 2 | 5.9500000 | 23.950000 | 32.353330 | 33.511670 | |
| ANOVA TABLE | | | | | |
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 1023.2490 | 1.49 | | |
| A | 2 | 4745.2790 | 6.90 | 28.8377 | |
| B | 3 | 972.08180 | 1.41 | NS | |
| AB | 6 | 350.75400 | .51 | NS | |
| Error | 11 | 687.28150 | | | 109.50 |

pH (16)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 5.3050000 | 5.3900000 | 5.5650000 | 5.6400000 | 4.5650000 |
| 6 | 5.3350000 | 5.6500000 | 5.5350000 | 5.4100000 | 5.7300000 |
| 11 | 5.7650000 | 5.7300000 | | | |

| FACTOR | MEANS | | | |
|--------|-----------|-----------|-----------|-----------|
| 1 | 5.4750000 | 5.2712500 | 5.6587500 | |
| 2 | 5.0933340 | 5.4850000 | 5.6600000 | 5.6350000 |

| ANOVA TABLE | | | | | |
|-------------|------|---------------|---------|---------|------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | .65104170E-03 | .04 | | |
| A | 2 | .30044560 | 17.17 | .145503 | |
| B | 3 | .41075300 | 23.48 | .168012 | |
| AB | 6 | .84835470E-01 | 4.85 | .291006 | |
| Error | 11 | .17496740E-01 | | | 2.42 |

PLW (19)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 4.9300000 | 14.710000 | 15.965000 | 17.190000 | 3.6750000 |
| 6 | 14.440000 | 14.850000 | 16.710000 | | |

| FACTOR | MEANS | | | |
|--------|-----------|-----------|-----------|-----------|
| 1 | 13.198750 | 12.418750 | | |
| 2 | 4.3025000 | 14.575000 | 15.407500 | 16.950000 |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 309.58370 | 29.87 | | |
| A | 1 | 2.4338380 | .23 | NS | |
| B | 3 | 132.50600 | 12.79 | 5.38209 | |
| AB | 3 | .22916670 | .02 | NS | |
| Error | 7 | 10.363840 | | | 25.13 |

FIRMNESS (19)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 5.1000000 | 5.0000000 | 4.8300000 | 4.6200000 | 6.7350000 |
| 6 | 4.4350000 | 4.6150000 | 4.7150000 | | |

| FACTOR | MEANS | | | |
|--------|-----------|-----------|-----------|-----------|
| 1 | 4.8875000 | 5.1250000 | | |
| 2 | 5.9175000 | 4.7175000 | 4.7225000 | 4.6675000 |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|--------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 2.6406250 | 6.61 | | |
| A | 1 | .22564700 | .56 | NS | |
| B | 3 | 1.4786890 | 3.70 | NS | |
| AB | 3 | .94068400 | 2.36 | NS | |
| Error | 7 | .39939660 | | | 12.62 |

TSS (19)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 14.700000 | 12.650000 | 13.150000 | 13.250000 | 16.550000 |
| 6 | 13.100000 | 12.400000 | 13.250000 | | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|-----------|--|
| 1 | 13.437500 | 13.825000 | | | |
| 2 | 15.625000 | 12.875000 | 12.775000 | 13.250000 | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | .39062500 | .41 | | |
| A | 1 | .60034180 | .63 | NS | |
| B | 3 | 7.2338870 | 7.59 | 1.63250 | |
| AB | 3 | 1.1957190 | 1.25 | NS | |
| Error | 7 | .95350870 | | | 7.16 |

ROTTING(19)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 8.8300000 | 20.690000 | 30.315000 | 48.680000 | 7.0300000 |
| 6 | 10.635000 | 26.660000 | 44.980000 | | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|-----------|--|
| 1 | 27.128750 | 22.326250 | | | |
| 2 | 7.9300000 | 15.662500 | 28.487500 | 46.830000 | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 579.60550 | 3.14 | | |
| A | 1 | 92.255860 | .50 | NS | |
| B | 3 | 1155.9840 | 6.26 | 22.7195 | |
| AB | 3 | 13.045570 | .07 | NS | |
| Error | 7 | 184.67810 | | | 54.96 |

pH (19)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 5.3800000 | 5.6250000 | 5.7050000 | 5.7450000 | 4.8400000 |
| 6 | 5.7000000 | 5.8700000 | 5.8000000 | | |

| FACTOR | MEANS | | | |
|--------|-----------|-----------|-----------|-----------|
| 1 | 5.6137500 | 5.5525000 | | |
| 2 | 5.1100000 | 5.6625000 | 5.7875000 | 5.7725000 |

| ANOVA TABLE | | | | | |
|-------------|------|---------------|---------|---------|------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | .61035160E-03 | .03 | | |
| A | 1 | .15014650E-01 | .83 | NS | |
| B | 3 | .41039020 | 22.77 | .224441 | |
| AB | 3 | .10414630 | 5.78 | .317407 | |
| Error | 7 | .18022810E-01 | | | 2.40 |

PLW(22)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 5.4900000 | 16.475000 | 17.045000 | 19.055000 | 4.2700000 |
| 6 | 16.090000 | 16.575000 | 18.650000 | | |

| FACTOR | MEANS | | | |
|--------|-----------|-----------|-----------|-----------|
| 1 | 14.516250 | 13.896250 | | |
| 2 | 4.8800000 | 16.282500 | 16.810000 | 18.852500 |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 394.02220 | 30.41 | | |
| A | 1 | 1.5371090 | .12 | NS | |
| B | 3 | 159.54260 | 12.31 | 6.01793 | |
| AB | 3 | .16129560 | .01 | NS | |
| Error | 7 | 12.957240 | | | 25.34 |

FIRMNESS (22)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 4.7150000 | 4.4500000 | 4.2300000 | 3.9000000 | 5.8850000 |
| 6 | 3.6850000 | 4.0850000 | 4.3500000 | | |

| FACTOR | MEANS | | | |
|--------|-----------|-----------|-----------|-----------|
| 1 | 4.3237500 | 4.5012500 | | |
| 2 | 5.3000000 | 4.0675000 | 4.1575000 | 4.1250000 |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|--------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 3.4224550 | 8.30 | | |
| A | 1 | .12600710 | .31 | NS | |
| B | 3 | 1.4058130 | 3.41 | NS | |
| AB | 3 | .68386840 | 1.66 | NS | |
| Error | 7 | .41241890 | | | 14.55 |

TSS (22)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|---------------|-----------|-----------|-----------|
| 1 | 13.800000 | 11.700000 | 11.550000 | 11.600000 | 14.450000 |
| 6 | 12.500000 | 12.200000 | 11.950000 | | |
| FACTOR MEANS | | | | | |
| 1 | 12.162500 | 12.775000 | | | |
| 2 | 14.125000 | 12.100000 | 11.875000 | 11.775000 | |
| ANOVA TABLE | | | | | |
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | .45507810 | .34 | | |
| A | 1 | 1.5004880 | 1.13 | NS | |
| B | 3 | 4.9505210 | 3.72 | NS | |
| AB | 3 | .35644530E-01 | .03 | NS | |
| Error | 7 | 1.3314380 | | | 9.25 |

ROTTING (22)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 33.585000 | 43.840000 | 67.985000 | 100.00000 | 23.520000 |
| 6 | 39.420000 | 55.235000 | 100.00000 | | |
| FACTOR MEANS | | | | | |
| 1 | 61.352500 | 54.543750 | | | |
| 2 | 28.552500 | 41.630000 | 61.610000 | 100.00000 | |
| ANOVA TABLE | | | | | |
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | 886.39840 | 10.01 | | |
| A | 1 | 185.42970 | 2.09 | NS | |
| B | 3 | 3882.8680 | 43.84 | 15.7344 | |
| AB | 3 | 32.658860 | .37 | NS | |
| Error | 7 | 88.577010 | | | 16.24 |

pH (22)

No. of reps.= 2 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 5.6750000 | 5.8250000 | 5.8500000 | 5.9750000 | 5.1250000 |
| 6 | 5.7750000 | 5.9350000 | 5.9350000 | | |
| FACTOR MEANS | | | | | |
| 1 | 5.8312500 | 5.6925000 | | | |
| 2 | 5.4000000 | 5.8000000 | 5.8925000 | 5.9550000 | |

| ANOVA TABLE | | | | | |
|-------------|------|---------------|---------|---------|------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 1 | .20385740E-01 | 2.73 | | |
| A | 1 | .77026370E-01 | 10.31 | .102190 | |
| B | 3 | .24904380 | 33.33 | .144518 | |
| AB | 3 | .78938800E-01 | 10.56 | .204379 | |
| Error | 7 | .74724470E-02 | | | 1.50 |

TSS/ACIDITY-10

No. of reps.= 3 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 19.943330 | 23.253330 | 25.260000 | 17.900000 | 24.360000 |
| 6 | 29.713330 | 24.133330 | 38.080000 | 27.150000 | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|--|--|
| 1 | 22.818890 | 23.991110 | 29.787780 | | |
| 2 | 20.658890 | 28.564450 | 27.374440 | | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 2 | 969.25510 | 26.01 | | |
| A | 2 | 125.31240 | 3.36 | NS | |
| B | 2 | 163.51900 | 4.39 | 6.09773 | |
| AB | 4 | 62.307460 | 1.67 | NS | |
| Error | 16 | 37.265110 | | | 23.91 |

TSS-ACIDITY-16

No. of reps.= 3 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 36.186660 | 47.780000 | 95.526670 | 26.156670 | 50.113330 |
| 6 | 75.193340 | 66.510000 | 71.713330 | 53.666670 | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|--|--|
| 1 | 59.831110 | 50.487780 | 63.963330 | | |
| 2 | 42.951110 | 56.535560 | 74.795560 | | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 2 | 8005.2910 | 13.45 | | |
| A | 2 | 428.94060 | .72 | NS | |
| B | 2 | 2298.0520 | 3.86 | 24.3727 | |
| AB | 4 | 1366.1320 | 2.29 | NS | |
| Error | 16 | 595.34950 | | | 42.00 |

TSS-ACIDITY-19

No. of reps.= 3 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 39.103330 | 72.096660 | 117.36330 | 34.300000 | 76.189990 |
| 6 | 105.39670 | 81.193330 | 81.810010 | 79.256670 | |
| FACTOR MEANS | | | | | |
| 1 | 76.187770 | 71.962230 | 80.753330 | | |
| 2 | 51.532220 | 76.698880 | 100.67220 | | |
| ANOVA TABLE | | | | | |
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 2 | 11474.380 | 14.62 | | |
| A | 2 | 173.96610 | .22 | NS | |
| B | 2 | 5434.2230 | 6.93 | 27.9800 | |
| AB | 4 | 1516.7480 | 1.93 | NS | |
| Error | 16 | 784.62630 | | | 36.71 |

TSS-ACIDITY-22

No. of reps.= 3 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 39.746670 | 109.83670 | 159.20330 | 52.600000 | 91.120000 |
| 6 | 111.95330 | 106.47670 | 115.70670 | 134.82670 | |
| FACTOR MEANS | | | | | |
| 1 | 102.92890 | 85.224450 | 119.00330 | | |
| 2 | 66.274440 | 105.55440 | 135.32780 | | |
| ANOVA TABLE | | | | | |
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 2 | 18946.080 | 20.22 | | |
| A | 2 | 2569.3000 | 2.74 | NS | |
| B | 2 | 10796.620 | 11.52 | 30.5756 | |
| AB | 4 | 1680.3600 | 1.79 | NS | |
| Error | 16 | 936.94730 | | | 29.90 |

Table H3 ANALYSIS OF FACTORIAL IN RANDOMISED BLOCK DESIGN (FRBD)

TRANSPORTATION (Duration X Treatment)

No. of reps.= 3 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|------------|------------|------------|------------|------------|
| 1 | 6.3266660 | 1.2433330 | .21666670 | .22666670 | 24.776670 |
| 6 | 12.2733330 | 11.0400000 | 10.6700000 | 34.6100000 | 15.1400000 |
| 11 | 14.2800000 | 13.4533330 | | | |

| FACTOR | MEANS | | | | |
|--------|-----------|------------|-----------|-----------|--|
| 1 | 2.0033330 | 14.6900000 | 19.370830 | | |
| 2 | 21.904440 | 9.5522220 | 8.5122220 | 8.1166670 | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 2 | 147.23980 | 22.06 | | |
| A | 2 | 968.98300 | 145.17 | 2.18715 | |
| B | 3 | 393.99780 | 59.03 | 2.52550 | |
| AB | 6 | 39.874710 | 5.97 | 4.37429 | |
| Error | 22 | 6.6747980 | | | 21.49 |

TRANSPORTATIONS (Package X Treatment)

No. of reps.= 3 No. of factors= 2
 Analysis of Factorial Experiment in RBD

| TREAT. COMBINATION MEANS | | | | | |
|--------------------------|-----------|-----------|-----------|-----------|-----------|
| 1 | 26.110000 | 13.936670 | 12.180000 | 11.380000 | 19.133330 |
| 6 | 6.4333330 | 5.7933330 | 5.0100000 | 20.470000 | 8.2866670 |
| 11 | 7.5633330 | 7.9600010 | | | |

| FACTOR | MEANS | | | | |
|--------|-----------|-----------|-----------|-----------|--|
| 1 | 15.901670 | 9.0925000 | 11.070000 | | |
| 2 | 21.904450 | 9.5522220 | 8.5122220 | 8.1166670 | |

| ANOVA TABLE | | | | | |
|-------------|------|-----------|---------|---------|-------|
| SOURCE | d.f. | M.S. | F-Ratio | CD(5%) | C.V. |
| Reps. | 2 | 968.98380 | 56.04 | | |
| A | 2 | 147.24030 | 8.51 | 3.52035 | |
| B | 3 | 393.99830 | 22.78 | 4.06495 | |
| AB | 6 | .94305420 | .05 | NS | |
| Error | 22 | 17.292380 | | | 34.59 |

VITA

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