# POST HARVEST BIOTECHNOLOGY TO INCREASE STORAGE UFE OF MANGO

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## ABSTRACT

A hypobaric storage system was developed to evaluate the storage life of mangoes under tropical conditions taking into consideration the pressure, temperature and humidity of storage conditions. The effects of these variables as well as pretreatments such as precooling and waxing on the ripening and quality of mangoes were evaluated based on firmness, total soluble solids, weight loss, decay, chlorophyll content and skin color change.

The results revea1ed that low pressure storage markedly delayed the ripening of fruit. Storage pressures of 100 and 60 rom Hg at 13°C were found to be most effective where the storage life of mangoes was extended up to 4 weeks. A temparature of 20°C was also observed to be effective for low pressure storage at pressures not lower than 150 mm Hg. In this case the storage life of mangoes was prolonged to 2.5 weeks. However, the qualify of stored fruit was lower than at 13°C All fruits stored at suba1mospheric pressure at 20°C and 13°C respectively riped 1 to 2 days and 4 to 5 days after they were transferred to shelf life at 31°C. The fruits softened slmilarly, but firmer-frults were observed when stored at lower pressures. Chemica1 waxing treatment was capable of retaining chlorophyll up to 20 days of storage but injured the skin after 20 days storage at high concentration wax treatmenta and ndmded the ripening process of mango after remova1 to room temperature conditions. Brown color dewIopment on the skin during storage resulted in an undesirable appearance on the samples.

Precooling treatment was found to be an effective method to prolong the storage life. At a 30°C precooling temperature, loss In firmness, loss in chlorophyll, sugar accumulation, increase in pH, and weight loss was observed to be higher than at 15°C precooling, Mangoes precooled to 15°C with low concentration (below 0.5%) chemical treatment were kept for up to 30 days in storage without loss in quality after ripening.


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## 1. INTRODUCTON

The mango fruit is of greet economic importance, especially in the developing countries, where annual yield is about 10,000 tonnes or more. Presently its econcmk value has been increasing due to its importance in the world market. Mangoes, which are climacteric fruits having a high metabolic rate have a short storage life in normal atmospheric conditions. Due to its increased demnd for export, its stomge life and quality is a major concern.

Mango cultivars grown in Thailand are usually harvested from the start of May b June. The problems associated with attempts b increase storage life of mangoes are. short picking season, short cornmercial storage life (Thompson. 1971). chilling injuries, abnormal ripening during prolonged storage etc. These problems spur interest for a search for better storage methods to prolong storage life and subsequent sheIf-life of mangoes. This would ensure a continuous supply of the produce during lean months so as to extend the marketing season.

Research to eva1uate ways to entend the stomge life of mangoes have been done in many countries. Refrigeration tends to delay ripening and senescense. However reduction in storage temperature is limited by susceptibility of the fruit to chilling injuriess(Abou Aziz, et at., 1976; Sadasivan et al, 1971). Some research has dealt with controlled atmosphere storage. In this method however, the commodity is not wntilated and the volatile substances which accumulate in the storage unit may limit the storage life or cause abnormal ripening. Subatmospheric pressure storage (Burg and Burg, 1966) was found to be suitable for perishable commodities, however, very little information is available about its use for tropical mango varieties.

It was therefore intended to conduct detailed studies on low pressure hypobaric storage of mangoes. A low pressure stomge system for use in developing countries was dewIoped. The quality aspects of stored products were evaluated and proper conditions for prolonged storage were identified. The effect of low pressure storage on the quality of mangoes was evaluated. The results are incorporated in this paper.

## 2. REVIEW OF LITERATURE

Hypobaric storage was first introduced by Burg and Burg (1966). This method not only reduces $0_2$ concentration but also increased the diffusion of ethylene by evacuation from the tissues of the fruit, consequently extending the storage life (Wu et al. 1972). Burg (1973) noted that lowering the pressure does not cause the plant material 10 emanate ethylene, carbon dioxide or other volatiles such as aromas and flavors at more rapid equilibrium rates. Burg (1975) found that when the commodity Is transferred from hypobaric to atmospheric conditions it resumes emanations of volatiles at a normal rate unless it has entered a state of semi-dormancy.

Burg and Burg (1966) studied the storage of bananas at about 0.2 to 0.5 atmcsphedc pressures at 15 to 24$^{o}$C. They found that the storage life of the fruits wes doubled at 0.5 atmosphere and doubled again at 0.33

atmosphere. Burg (1975) also reported that Hadan mangoes rippered four times slower at 150 mm Hg. Apelbaum et al., (1977), and Spalding and Reader (1976) studied mango storage at 13°C for 3 to 4 weeks. They found that ripening of mango fruit was markedly delayed when atmospheric pressure in the chambers was reduced below 100 mm Hg. Wu et al. (1972) showed that it is possible to store tomatoes for 100 days using hypobaric storage at 102 mm Hg if the fruits are subsequently transferred to atmospheric pressure at 13°C and 90-95% RH. Salunke and Wu (1973) determined the effects of various levels of subatmospheric pressures on ripening behaviour and associated chemical changes of certain deciduous fruits like apricots, peaches, sweet cherries, pears and apples. They found that storage life of these fruits increased due to atmospheric storage.

Rapid cooling of produce to remove field heat can be achieved by many ways such as forced-air cooling, hydro-cooling, hydro-air cooling and vaccum cooling. It may be performed in the field or at the packing houses in bulk loads pallet-bin boxes or in shipping containers (Shelwfelt, 1986). Economic benefits of early precooling have been described by Freeman (1984).

Waxing by dipping fruits in wax emulsion has been reported to reduce the rate of vitamin C and titratable acid loss and sugar accumulation (Chaudhary et al., 1979 and Sheikh et al., 1977). Sundraraj et al. (1972) showed that coating the skin of fruit with a thin wax file increases the storage life of mango and reduced weight loss.

# 3. MATERIALS AND METHOD

## 3.1 Hypobaric Systems

Four storage chambers were made from 30.5 cm dia PVC pipes of 1 m length. These chambers were made gas tight. Provision was made to measure temperature inside the chamber by thermocouples. Inlet and outlet holes at the top were made for air entry and exit. A stainless steel wire mesh was provided 5 cm above the bottom of the chambers to allow excess moisture to drip down the bottom of the chambers. The cooling chambers were made from No. 20 gage galvanized iron sheets, with a cover to control the inside temperature. Cooling was done by using an evaporator coil immersed into the water inside the cooling tank, where the storage chamgers were also immersed.

The system control board was composed of two manifolds for supply and exhaust of air. The supply manifold connected to the humidifier consisted of needle valves which controlled the humidified air flow into the storage chamber. The exhaust manifold on the other hand served as the suction port of the vaccum pump.

## 3.2 Storage system

The storage system consisted of a vaccum pump to evaluate air from the storage chambers. In-coming air was humidified by bubbling it through water contained in a 2000 ml Erlenmeyer side arm flask. The hypobaric chambers were placed in a controlled temperature space. A simplified refrigeration system to reduce cost during continuous operation was provided. Cooling was done by using an evaporator coil which cooled the water inside the controlled temperature chamber.

A small air pump was used to supply air inside the chamber. Thermocouples were calibrated by using standard thermometers. Temperature was recorded during the whole duration of the experiment on a temperature recorder. Two oil-sealed vaccum pumps were used. The vaccum regulators were used to regulate the amount of vaccum inside each storage chamber. A humidity sensor device was used to measure the relative humidity in each chamber.

The firmness of mangoes before storage and at different periods of storage was measured with an instron testing machine. A hand refractometer was used to measure total sugars.

## 3.3 Methodology

Fig. 2 shows a flowchart describing the experimental method used in this investigation. Mature green mangoes of 'O Krong' variety were purchased from the wholesale market. Decay and mould free fruits were selected and washed to remove sticky sap. These fruits were divided into comparable lots and put in PVC chambers maintained at 20°C and 13°C. Each chamber contained 100 fruits. To appraise shrinkage, fruits were weighed before and after storage in the chambers.

A lot of washed sample was held at room temperature of about 31°C which served as control. The samples were stored in the chambers at 20°C for 2-5 weeks in the first experiment and 13°C for 4 weeks in the second set of experiments. The samples were tested at normal pressure of 760 mm Hg and at three different levels of subatmospheric pressures of 150, 100 and 60 mm Hg. The storage samples were opened periodically and fruit samples consisting of about 15 to 20 fruits were taken out for observation and analysis. They were checked for weight loss, pulp firmness, total sugars, amount of decay, and degree of skin color change. Pulp firmness was tested by the instron machine. A 1.6 mm diameter punch was used to puncture fruit at five different locations at loading speeds of 50 mm/min.

The amount of decay was assessed after storage and at the soft- ripe stage on the basis of aggregate percentages of surface areas visibly infected. Anthracnose decay was rated as, trace (20% or less of surface area) slight (2-10%), moderate (10-20%) and severe (more than 20%). Stem-end rot was rated as trace (barely noticeable, spreading less than 3 mm from base of the stem), slight (spreading 3-7 mm), moderate (spreading 8-13 mm), and severe (spreading more than 13 mm). Percent green skin areas were rated as mature green (100% green), breaker (90-95% green), quarter ripe (70-75% green) and full ripe (2% less green).

For the precooling treatment the mangoes were treated with hot water and fungicide to prevent anthracnose infection. The cooling rates of mangoes were fixed at 15°C through prior experimentation.In the first storage experiment, mangoes were transported to cooled water of 15°C until the temperatures were reduced to 15°C, 20°C and 30°C, respectively and then dipped in 0.50%, 0.85% and 1% concentrations. In the second storage experiment, mangoes were cooled at 15±1°C and then dipped in 0.5%, 0.3% and 0.1% concentrations of a commercial waxing material.

Mangoes were stored at optimum atmospheric pressure and relative humidity obtained in the previous experiment, Fruits were tested for weight loss, chlorophyll, pH, total soluble solids and firmness (Chesson and Moor, 1985). The Magness-Taylor force and Yield-Point force were read on an Instron machine. The rupture force was measured by a special load cell designed for this purpose. The chlorophyll was extracted from tissues using the standard method proposed by A.O.A.C. (1984).

# 4. RESULTS AND DISCUSSION

## 4.1 Effect of low pressure on constituent changes of mangoes

Mangoes stored at normal atmospheric conditions at 31°C (control) lost 10.2% of their total weight during a period of 7 days. The weight loss of fruits stored at 760 and 150 mm Hg pressure at 20°C, was lower during the entire storage. After 17 days, weight loss was only 6% and 8% respectively. Fig. 3, shows the weight loss of fruits at 20°C for various pressures. For the samples stored at 13°C and 760 mm Hg, the weight loss after 22 days was 1.42% of the total weight. However, for the same temperatures but at subatmospheric pressure storage, the weight loss reached about 7.29%, 10.20 and 14.7% at 150, 100 and 60 mm Hg respectively, Fig. 4.

The softening of mangoes was rapid when stored at 20oC both at atmospheric and subatmospheric pressures. An initial firmness of 3.6 kg before storage decreased to 1.7-1.2 kg after 7 days of storage. However fruit softening was delayed considerably when stored at subatmospheric pressures at 13oC. Fig. 5 shows changes in pulp firmness of mangoes during storage at 13°C under various pressures.

For fruits stored at 20°C, the total solublel solids increased from an initial 14% brix to 15-16% brix after 7 days of storage. The highest level of soluble solids occurred during 11-13 days of storage but decreased after 13 days of storage. The soluble solids in the fruits stored at 13°C were markedly delayed Fig. 6.

Soluble solids in the controlled sample increased from 12.9% brix to 21.2% brix in 7 days. However, the total soluble solids in fruits stored at subatmospheric storage increased to only 12-13 brix for the same period of storage.

Control fruits became almost half life after 7 days, at 20°C but the fruits stored at the same temperature but at 100 mm and 150 mm Hg pressures remained 50% greener even after 17 days of storage. The fruits stored at 13°C were almost green even after 17 days of storage, Fig. 7.

Higher incidence of decay in mangoes stored under low pressure at 20% was observed compared to the fruits stored at 13°C.

## 4.2 Effect of low pressure storage on quality of mangoes

Mangoes stored at 150 mm Hg for 17 days and at ambient temperature of 20°C, maintained very good quality and appearance as compared to those stored at much lower pressures under the same condition. Fruits stored at 150 mm Hg had a much lower rate of weight loss than those fruits stored at 100 and 60 mm Hg. The fruits stored at 60 and 100 mm Hg were firmer and had higher amount of total soluble solids. It was observed that mangoes stored at 150 and 100 mm Hg, lost their green skin color at a slower rate than the fruits stored at 60 mm Hg. The incidence of decay was observed to be lower in fruits stored at low pressure conditions, compared to those stored at normal pressure.

The quality of fruits was observed to be related to the length of time of storage of fruits under low pressure, Table 1. The storage life of mangoes was extended on-week as compared to those stored at normal atmospheric conditions.

## 4.3 Effect of low pressure on the storage life and shelf life of mangoes

The low pressure storage extended the storage life of mangoes to one-week more than normal storage conditions at 20°C and two and a half weeks more than normal at 13°C. The results indicated that low pressure did not affect the fruit quality contrary to the results of Apelbaum et al (1977), during ripening. Fruit firmness, total soluble solids content and skin color development was even better at low pressure, than storage at atmospheric pressure.

## 4.4 Effect of temperature on mango storage under low pressure

It was found that maximum storage life under normal pressure and at 31°C was only 10 days considering an acceptable quality of fruit. Mangoes stored under normal pressure at 20°C and with a supply of humidified air had a very low rate of weight loss. Storage under low pressure at 20°C and similar humidity conditions resulted in longer storage life. The percentage of fruits acceptable and of good quality was higher at 20°C under lower pressure for 17 days. However storage of mangoes at lower temperature of 13°C gave much better results than 20°C. Fruits remained green after 17 days and even until 25 days under 60 and 100 mm Hg.

## 4.5 Effect of humidtty in low pressure storage

The humidity inside the chambers affected the incidence of decay in fruits. Storage at 760 mm Hg and at 95-100% RH had a higher incidence of decay than fruits stored at 150, 100 and 60 mm Hg at 85, 55 and 34% RH respectively.

In general during these hypobaric studies, ripening of mango was found to be delayed considerably when the atmospheric pressure in the storage chamber was reduced to below 100 mm Hg at 13°C, thus prolonging storage life. Low pressure storage markedly retarded the yellowing, softening and deterioration of mangoes which is a severe problem during normal storage conditions.

Results indicated that mangoes stored at 13°C and 100-60 mm Hg gave very good results after 4 weeks in storage. The application of subatmospheric storage methods to green mango fruits seems to be very promising in prolonging storage life.

### 4.5 Effect of precooling and waxing

For precooling treatment, mangoes were cooled from 32.2°C to 30°C, 20°C and 15°C. For the waxing treatment, wax concentrations of 1%, 0.85% and 0.7% were used. Fig. 8 shows weight loss of mango for different precooling treatments. Mangoes stored at normal atmospheric conditions at 25°C lost 21.8% of its weight after 10 days of storage, while the weight loss of mango stored both at low pressure and normal atmosphere with constant low temperature (15°C) were below 6% after 25 days of storage.

The firmness ot mangoes for different treatments was studied. A maximum force of 4 to 5 kg, 6 to 12 kg, 10 to 12 kg were measured for 30°C, 20°C and 15°C precooled samples after 25 days of storage. The changes in the pulp rupture force during 25 days storage of mango for different precooling and waxing treatments showed that maximum 0.4 to 1.8 kg, 4.9 to 5.4 kg and 1.3 to 8.6 kg firmness was observed for 30°C, 20°C and 15°C precooled samples respectively.

An initial Magness-Taylor force of 15 kg was measured before storage. Fig. 9 shows changes in Magness-Taylor force in fruits for 0.7% waxing under various precooled temperatures.

Chlorophyll changes for 10% and 0.85% waxed treatments were very similar. There was little difference in chlorophyll changes for each treatment before 15 days of storage. However after 20 days, the decrease in chlorophyll content was rapid towards browning and the whole peel of fruit browned after 25 days of storage. Under 1% waxed treatment, the increase in total soluble solids was markedly delayed for the sample with 15°C precooling treatment. Fig. 10 shows changes in soluble solids at 1% waxing treatment for different precooled temperatures. In the 0.7% wax treatment groups, samples with 20°C and 15°C precooling treatments markedly delayed the accumulation of soluble solids.

The weight loss of 1% waxed fruit for the 30°C precooled sample was higher than for 0.85%, and 0.7% treatment aftet 20 days of storage. Weight loss during 20 to 25 days of storage at 1% concentration increased rapidly. In general for all treatments it was observed that waxing lowered weight loss compared with the samples without wax treatment. Waxing treatment was observed to also affect the peel and pulp rupture force. Waxing concentrations of 0.7% and 0.85% were found to be more suitable for higher firmness in mango for 25 days of storage. The maximum pulp rupture force remained at 6.2 and 4.7 kg after 25 days for unwaxed samples. For waxed samples rupture force remained at 11.1 kg.

The change in ph of mango samples was affected by the different concentrations of wax treatments However, there was no significant difference between the 1%, 0.85% and 0.7% samples under various precool ing temperatures.

The effect of waxing concentration on different constituents of mango was also studied. Weight loss, firmness, acid and total soluble solids were almost the same for all waxing treatments. However, they were significantly different from the non treated samples.

## 4.6 Effect of precooling and waxing on storage life

Mangoes precooled at 15°C had a higher storage quality compared to those precooled at 20°C and 30°C in terms of low weight loss, firmness, low pH and low sugar accumulation. Waxing concentrations were found to affect the weight loss. Weight loss at 0.5% concentration was slightly higher than the other two concentrations.

Maximum storage life for mango precooled to 30°C and 20°C with 1% and 0.85% waxing treatments was 20 days. for those precooled to 15°C with 1% to 0.7% waxing and those precooled to 30°C and 20°C with 0.7% waxing, maximum storage was 25 days, after which brown color developed.

## CONCLUSIONS

The application of hypobaric storage to green mango fruits was found to prolong storage life. Storage under a pressure range of 100-60 mm Hg at 13°C was found to give the best results. At low pressure storage, mangoes developed excellent color when ripe both in the pulp and skin. The total soluble solids did not differ significantly with the control. High relative humidity is required to minimize weight loss during storage.

The application of precooling treatment prolonged the storage life of mango under hypobaric storage. Mango precooled at 15°C was better in quality as compared to 30°C and 20°C. Waxing treatment of mangoes resulted in retarding the ripening metabolic process during storage or out of storage. The optimal pretreatment was found to be precooling to 15°C and application of wax, for hypobaric storage.

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Table 1. Quality of "Okrong" Mangoes Stored at 20°C at Different Storage Pressures.

| Storage Time (Days) | Storage Pressure (mm Hg) | Shelf Life | Weight Loss (%) | Pulp Firmness (kg) | Total Sugars (% brix) | Color Change | Decay (%) |
|---|---|---|---|---|---|---|---|
| 0.00 | unstored | 10.00 | 0.00 | 3.6 | 13.98 | 100 | 0.00 |
| 7.00 | 760.00 | 2.00 | 2.10 | .78c | 15.40a | 64b | 4.00 |
| | 150.00 | 3.00 | 3.60 | .90bc | 15.70a | 86a | 3.00 |
| | 100.00 | 3.00 | 8.22 | 1.22a | 16.60a | 94a | 1.00 |
| | 60.00 | 3.00 | 5.30 | 1.10ab | 16.20a | 84a | 3.00 |
| 9.00 | 760.00 | 2.00 | 3.03 | .61b | 16.40a | 54bc | 9.00 |
| | 150.00 | 3.00 | 4.74 | .67b | 16.18a | 81a | 7.00 |
| | 100.00 | 3.00 | 8.80 | .88a | 17.18a | 74ab | 3.00 |
| | 60.00 | 3.00 | 8.25 | .75ab | 16.64a | 61ab | 7.00 |
| 11.00 | 760.00 | 2.00 | 3.36 | .67ab | 16.63a | 40c | 11.00 |
| | 150.00 | 2.00 | 4.97 | .54b | 16.73a | 75a | 8.00 |
| | 100.00 | 2.00 | 10.60 | .80a | 18.53a | 60b | 5.00 |
| | 60.00 | 2.00 | 9.07 | .62ab | 17.50a | 58b | 8.00 |
| 13.00 | 760.00 | 1.00 | 3.70 | .48a | 16.88a | 37b | 11.00 |
| | 150.00 | 1.00 | 5.20 | .52a | 17.20a | 58a | 9.00 |
| | 100.00 | 1.00 | 12.95 | .63a | 18.23a | 56a | 6.00 |
| | 60.00 | 1.00 | 11.03 | .57a | 18.17a | 56a | 10.00 |
| 15.00 | 760.00 | 1.00 | 5.48 | .44a | 14.84b | 31b | 13.00 |
| | 150.00 | 1.00 | 7.11 | .46a | 15.86ab | 54a | 15.00 |
| | 100.00 | 1.00 | 15.05 | .55a | 16.30ab | 52a | 9.00 |
| | 60.00 | 1.00 | 14.46 | .47a | 17.96a | 38ab | 14.00 |
| 17.00 | 760.00 | 1.00 | 6.05 | .57a | 16.00a | 26b | 15.00 |
| | 150.00 | 1.00 | 8.14 | .52a | 15.92a | 52a | 20.00 |
| | 100.00 | 1.00 | 17.82 | .59a | 17.86a | 50a | 12.00 |
| | 60.00 | 1.00 | 14.69 | .59a | 17.96a | 36ab | 16.00 |

* Mean separation in columns by Duncan's Multiple Range test, 5% level.

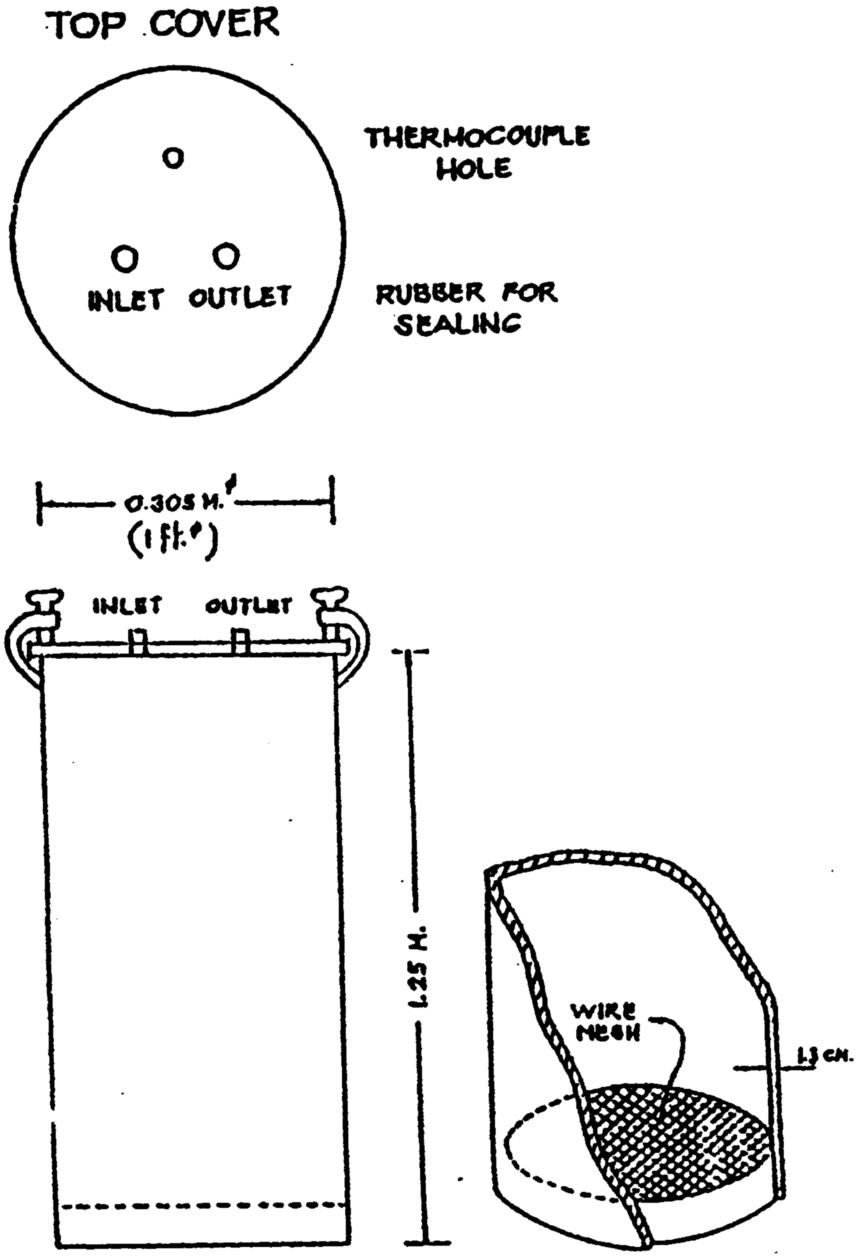


Fig. 1 Schematic diagram of a hypobaric storage chamber.

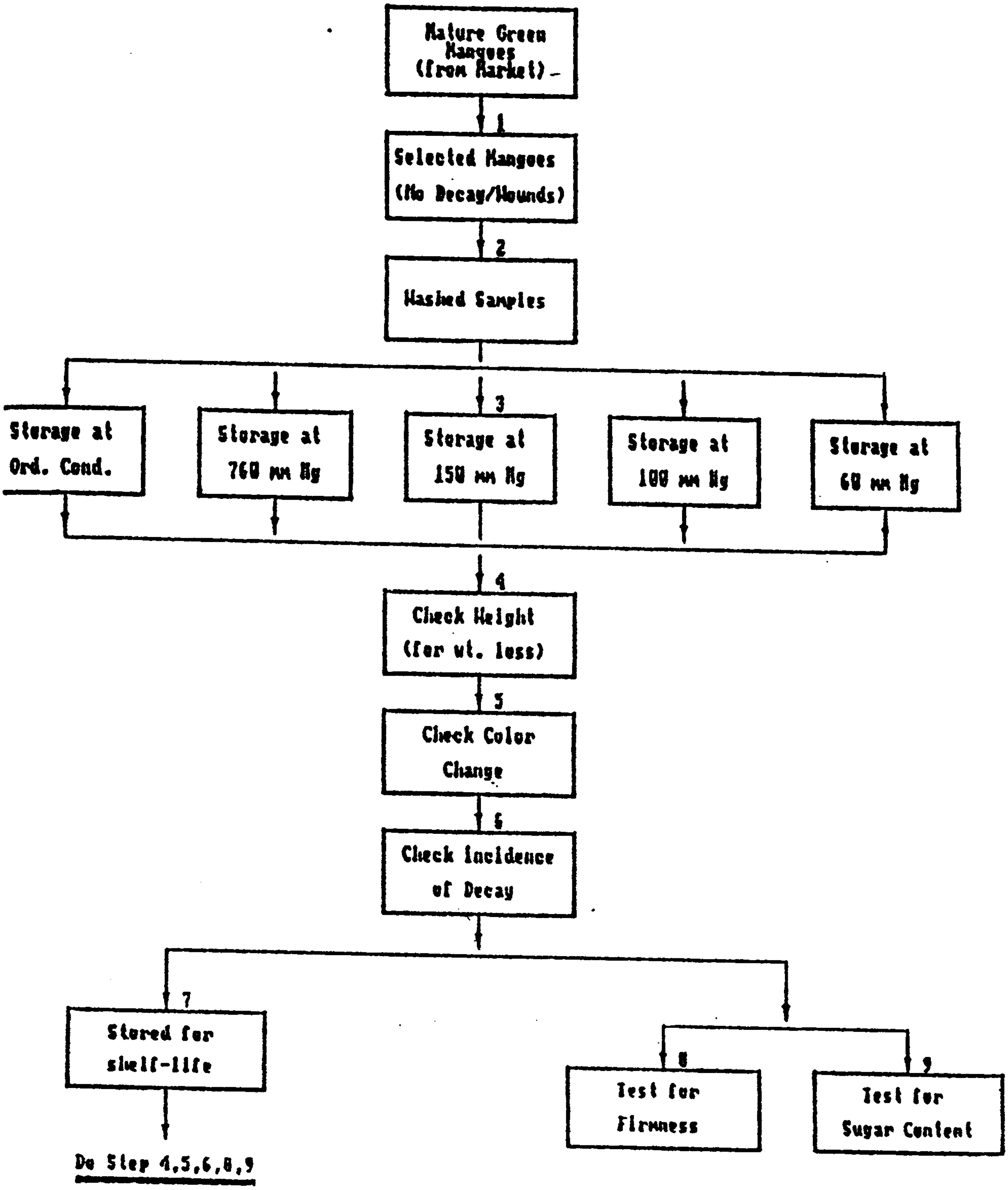


Fig. 2 Flow diagram of the method used in the experiment.

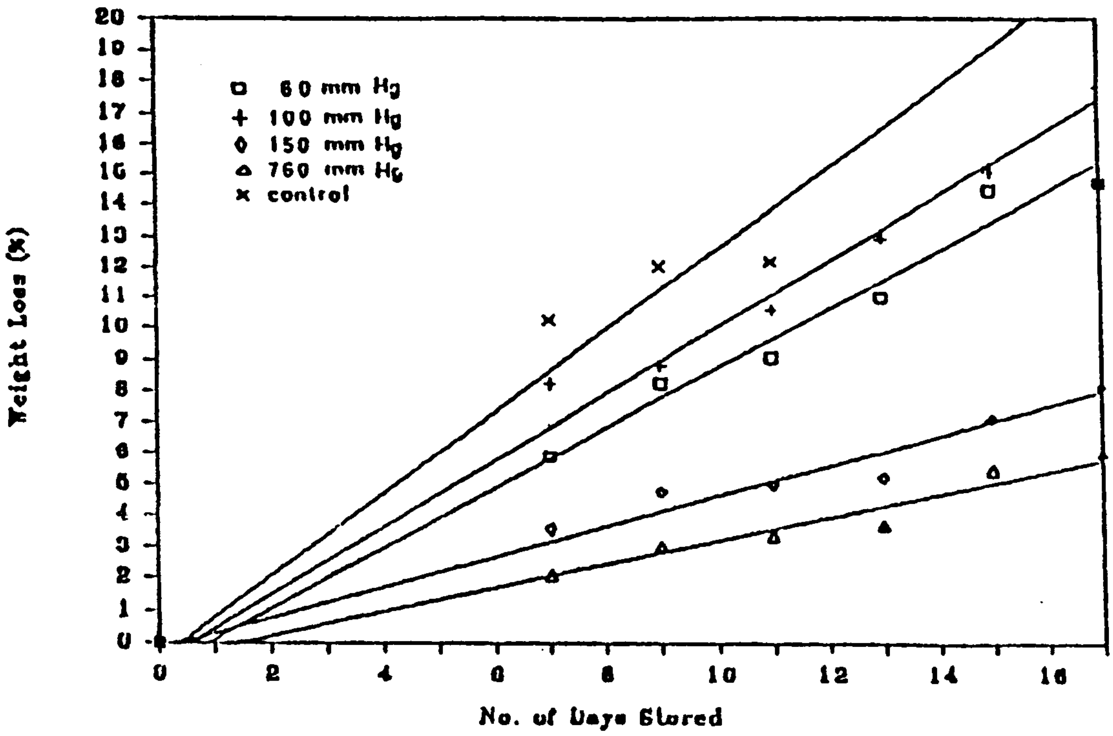


Fig. 3 Weight loss of mango during storage at 20°C under various pressures

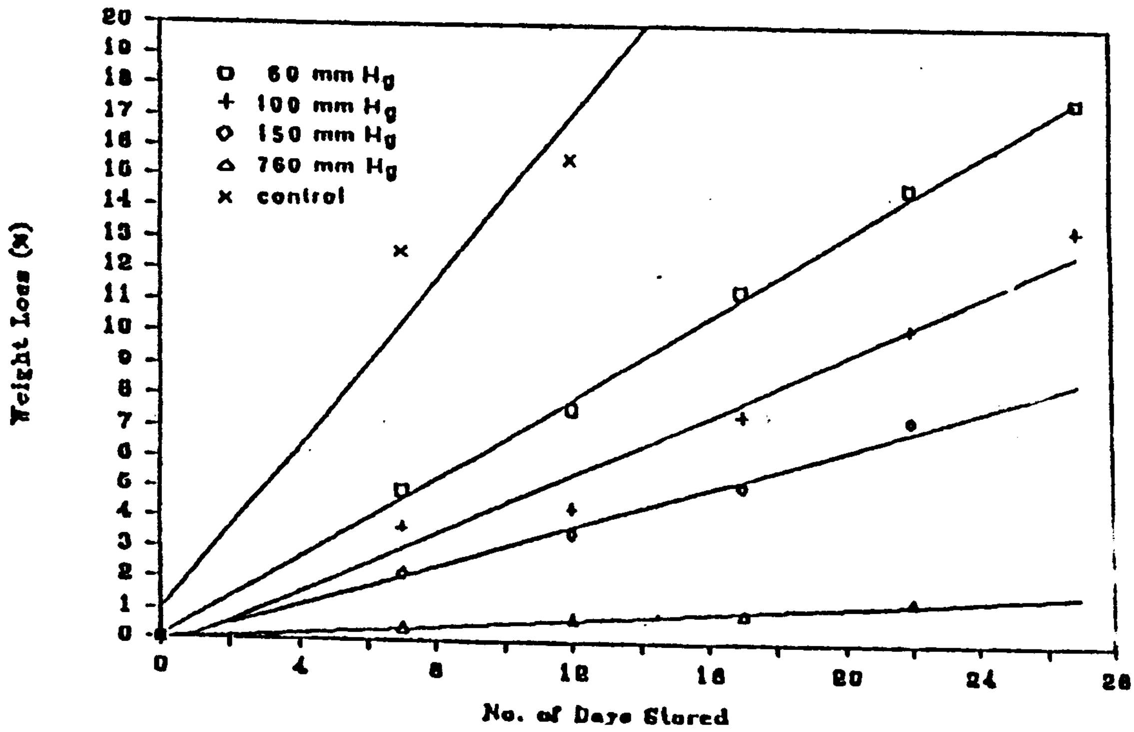


Fig. 4 Weight loss of mango during storage at 13°C under various pressures.

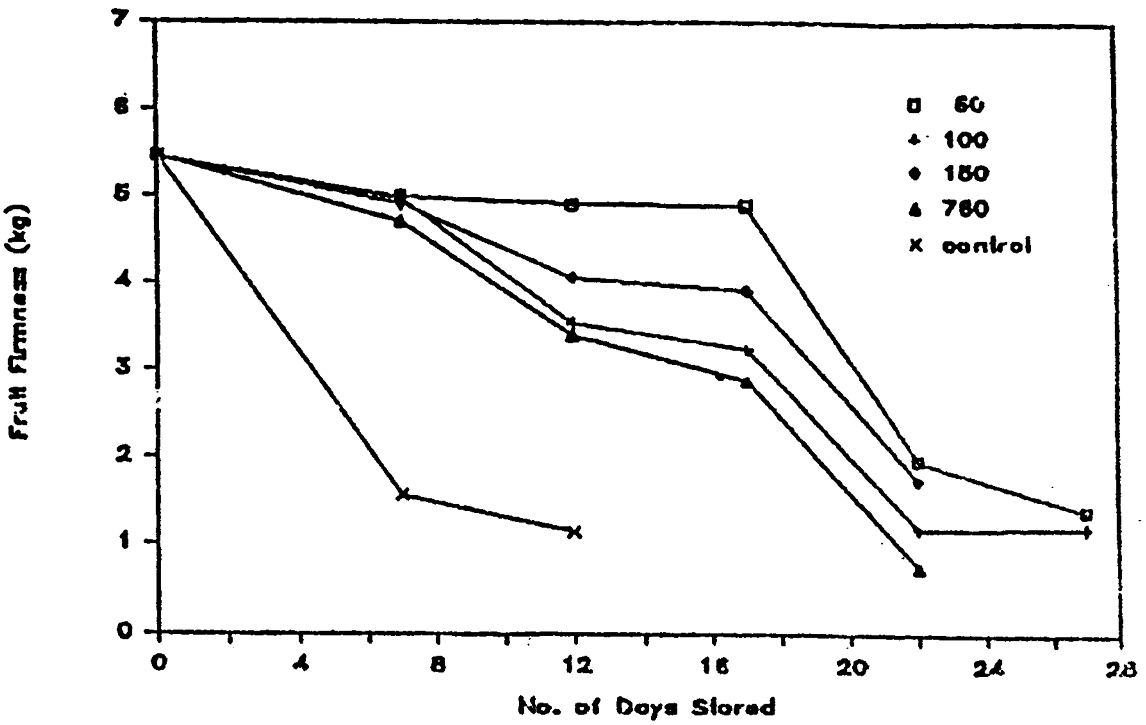


Fig. 5 Changes in pulp firmness of mango during storage at 13°C under various pressures.

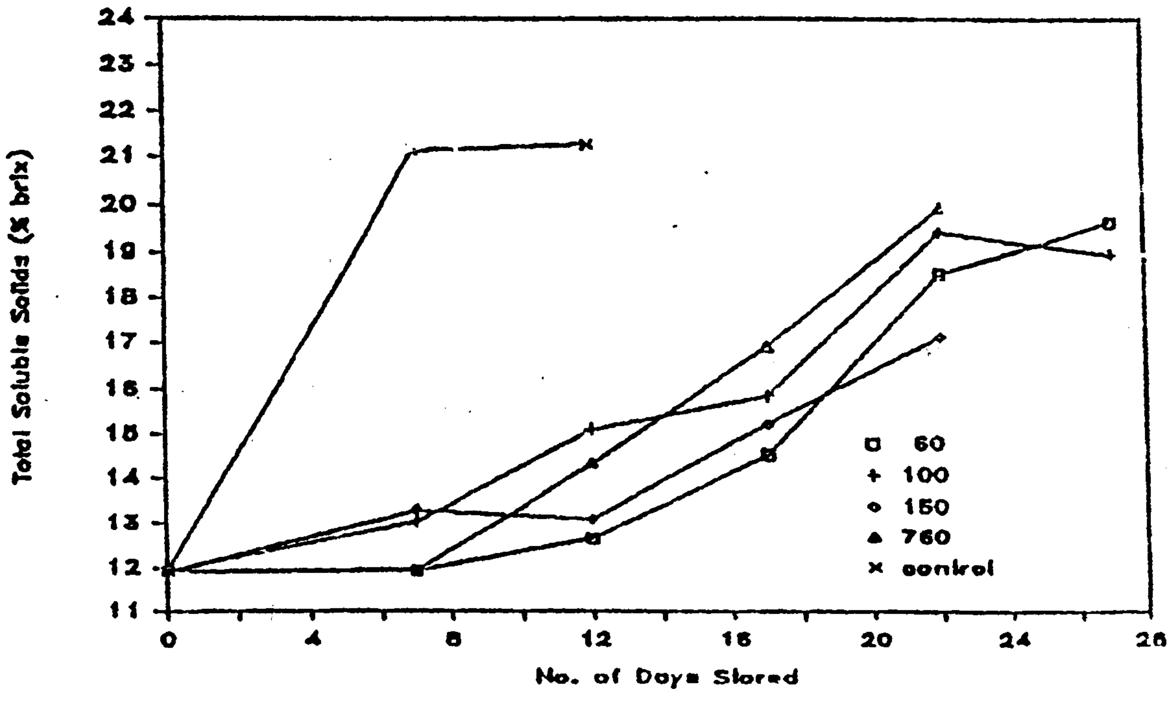


Fig. 6 Changes in total soluble solids content of mango stored at 13°C under various pressures.

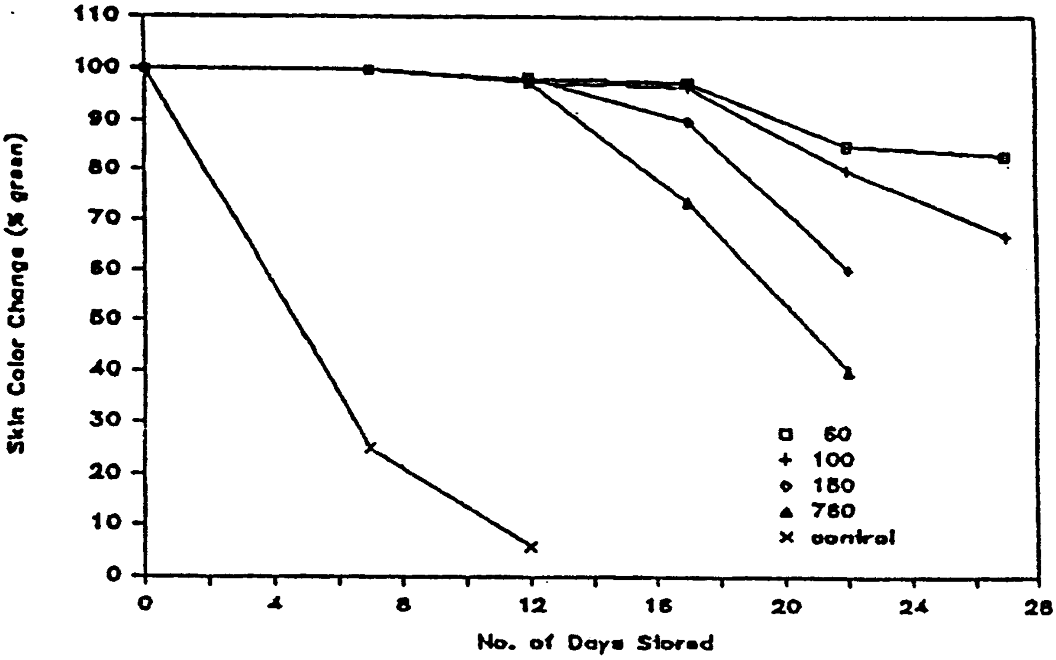


Fig. 7 Changes in skin color of mango stored at 13°C under various pressures.

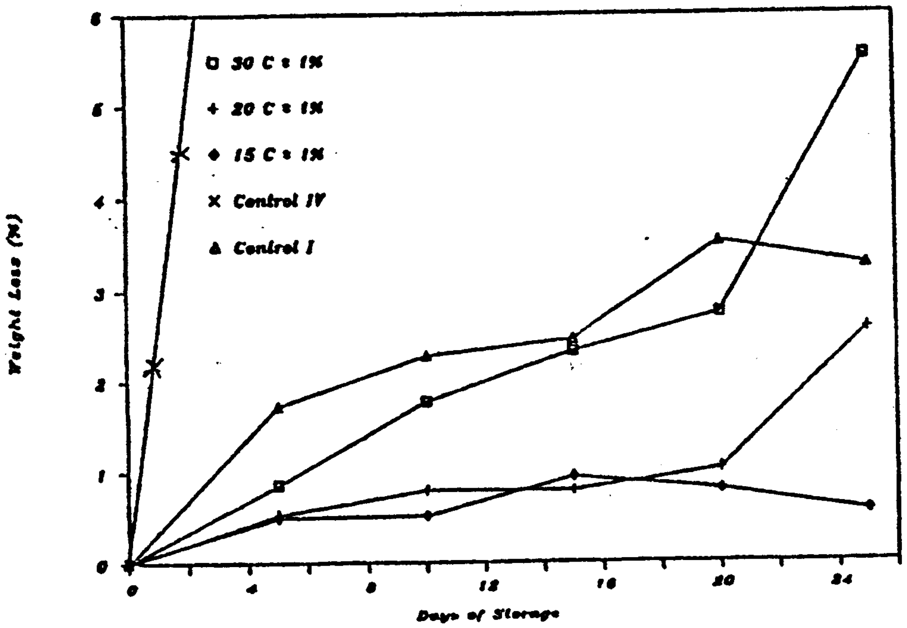


Fig. 8 Weight loss of mango with 1% chemical waxing durin storage under various precooled temperatures.

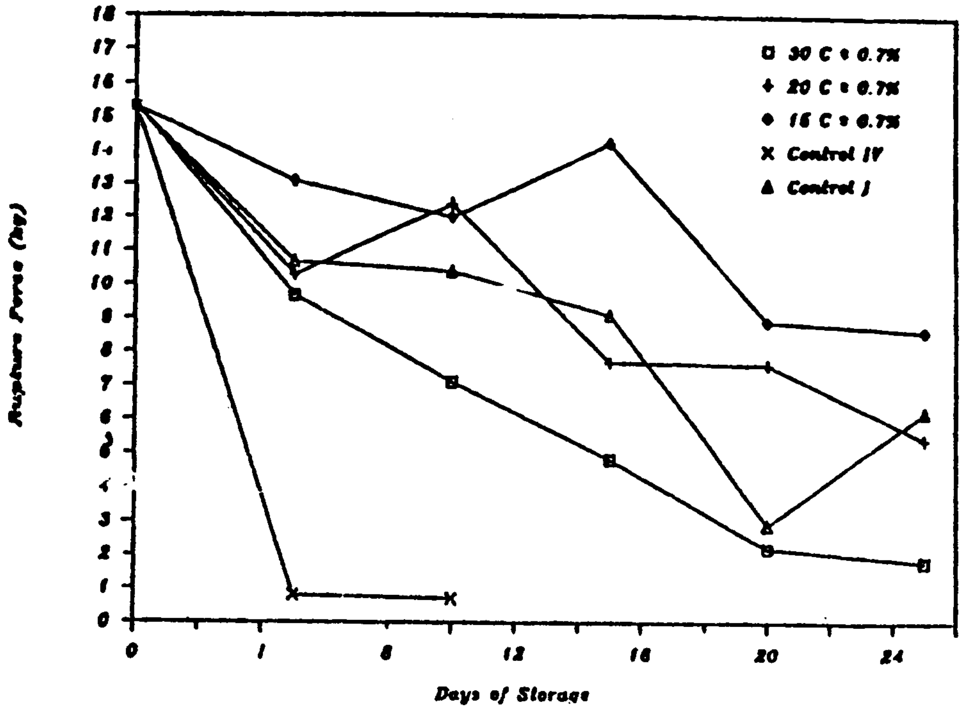


Fig. 9 Changes in rupture force of mango with 0.7% chemical waxing during storage under various precooled temperatures.

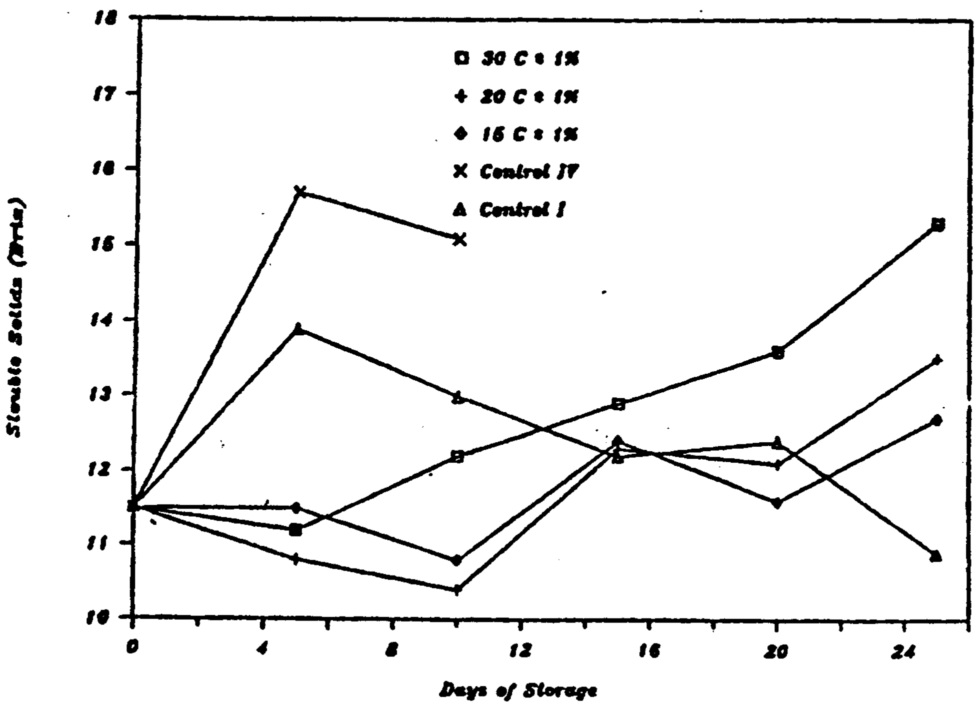


Fig. 10 Changes in total soluble solids of mango with 1% chemical waxing during storage under various precooled temperatures.