Effect of Pro-Long on the storage of mango fruit

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A Master's Thesis
submitted in partial fulfilment of the requirements for the award of
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Grimsby College of Technology.
Post-harvest treatment of mango (Mangifera indica L.) with Pro-long was studied. Mature green mangoes pre-treated with benomyl fungicide (in order to reduce spoilage due to fungal attack during storage) were dip-treated with different concentrations of Pro-long and stored at $13(\pm 2)\,^\circ\mathrm{C}/85-95\%\,\mathrm{R.H.}$ (optimum low-temperature) and $25(\pm 2)\,^\circ\mathrm{C}/85-95\%\,\mathrm{R.H.}$ (tropical ambient condition) respectively.

Physico-chemical changes during ripening were studied and the fruits were organoleptically evaluated to study consumer response. The shelf-life of Pro-long treated mangoes increased considerably under both conditions of storage. 1.0% Pro-long was found to be the best concentration for use on mango under optimum low-temperature storage conditions while 0.75% Pro-long produced best results during storage under tropical ambient conditions. The loss in physiological weight was also retarded in Pro-long treated fruits.

The use of higher concentrations of Pro-long produced anaerobic conditions in the mango fruit resulting in a marked reduction in the carotenoid content and a considerable increase in acidity thus adversely affecting its organoleptic qualities. Significant levels of ethanol were detected in mangoes treated with high concentrations of Pro-long.
ACKNOWLEDGEMENTS

I would like to thank Mr. R.K. Proudlove and Prof. J. Mann for their encouragement and supervision and Dr. S.W. Hanson for his invaluable help and guidance in several aspects of the work. I am also grateful to Dr. W.R.B. Arthur for his critical comments on this study.

I also wish to thank the staff of the instrumental and food processing laboratories of Grimsby College of Technology. The assistance extended by the college librarian in obtaining references is also acknowledged.

I also wish to thank my external supervisor, Mr. D.F. Cutts and Mr. J.F. Skiba of Geest Industries Ltd., for arranging the supply of raw materials and for taking such keen interest in this work.
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INTRODUCTION

The mango, *Mangifera indica* L., is the second most important tropical fruit (banana occupies the first place) in terms of production and acreage with an annual production of over 14 million tonnes (FAO, 1980). India is the largest producer of choice table varieties with an annual production of 9.5 million tonnes (FAO, 1980).

In recent years, the rich qualities of this fruit have become acceptable in many parts of the world and it is relished for its succulence, exotic flavour and delicious taste. Generally the fruit blends well with dairy products. It may be eaten fresh sliced, chopped or ground into a purée. In western food dishes, the mango can often be substituted in traditional uses for apples or peaches.

In view of the expanding world trade in mangoes in recent years and the steady increase in production (see Table 1), increased emphasis is being placed on storage and transport of the mango fruit for long-distance shipment. Therefore, preservation of this fruit in the fresh form for extended periods of time without loss of quality is an immediate necessity. This involves a sound knowledge of pre- and post-harvest physiology and biochemistry of the fruit. Storage diseases and damage during transit have restricted the fruits export potential because of its delicate and perishable nature.

Transport and storage systems have been the focus of research and development for many years and it has long been recognised that refrigeration and gas-controlled warehouse storage are both capital intensive to install and costly to run. A sugar based coating under the trade mark "Pro-long" has recently been introduced to the market and has already been successfully used in extending the shelf-life of bananas at a much reduced cost and shows great promise for use on a wide range of fruit and vegetables.
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<td>Zaire</td>
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<td>Rest (Benin, Central African Republic, Chad, Congo, Egypt, Ghana, Ivory Coast, Malawi, Mozambique, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Upper Volta)</td>
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<td>Haiti</td>
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<td>610</td>
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<td>Rest (Cayman Islands, Cuba, Dominica, El Salvador, Guadeloupe, Honduras, Jamaica, Martinique, Panama, St. Lucia, St. Vincent)</td>
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<td>958</td>
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<td>Brazil</td>
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<td>Venezuela</td>
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<td>Rest (Argentina, Bolivia, Columbia, Ecuador, Guyana, Paraguay, Peru)</td>
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<td>Bangladesh</td>
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<td>China</td>
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<td>211</td>
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<tr>
<td>India</td>
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<td>9000</td>
<td>9300</td>
<td>9500</td>
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<td>Indonesia</td>
<td>300</td>
<td>418</td>
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<td>Pakistan</td>
<td>486</td>
<td>561</td>
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<td>Philippines</td>
<td>143</td>
<td>335</td>
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<td>Rest (Israel, Kampuchea, Laos, Malaysia, Oman, Sri Lanka, U.A.E.)</td>
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<td>REST OF THE WORLD (Australia, Cook Islands, Oceania, Somoa and others)</td>
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1 The data are taken from the FAO Production Yearbook (FAO, 1980) and do not include the USA, Guatemala, Costa Rica, Nicaragua and other minor mango growing countries.
2. LITERATURE SURVEY

2.1 HISTORY AND ORIGIN OF THE MANGO

The mango, *Mangifera indica* L., has been known as a cultivated species for four to six thousand years (Singh, 1960). The mango was thought to have originated in India, but studies (Council for Scientific and Industrial Research, 1962) indicate that it probably originated in the Assam-Burma-Thailand region. As early as 1563 the name "Mangos" (Tamil - a south Indian language) was used for the mango in "Colloquies on Simples and Drugs of India" by Garcia de Orata (Singh, 1960) and the common English term and the botanical name *Mangifera indica* L., originate from this ancient name. There are literally hundreds of varieties, and Singh (1960) gives an interesting insight into how many of them got their names. A list of principal commercial varieties of mango is given in Table 2.
<table>
<thead>
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<th>Country</th>
<th>Cultivated Table Varieties</th>
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<tr>
<td></td>
<td>Fleshy with low fibre</td>
<td>Juicy with soft fibre</td>
</tr>
<tr>
<td>India</td>
<td>Alphonso, Dashehari, Chowsa, Bombay green, Langra, Rumani,</td>
<td>Raspoonia, Nauras,</td>
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<tr>
<td></td>
<td>Bangalora, Swarnarekha, Pairi, Banganpalli, Neelum, Mulgoba</td>
<td>Mithwa Sundershah,</td>
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<td></td>
<td></td>
<td>Mithwa Ghazipur,</td>
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<td></td>
<td></td>
<td>Taimurya, Rasgola,</td>
</tr>
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<td></td>
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<td>SharbatI Begrain,</td>
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<tr>
<td></td>
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<td>Cherukurasam,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peddarasam</td>
</tr>
<tr>
<td>Philippines</td>
<td>Carabao, Pico</td>
<td></td>
</tr>
<tr>
<td>Pakistan</td>
<td>Sindhri, Bombay, Alphonso, Banganpalli, Fazli, Chousa, Langra,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gulab-khas</td>
<td></td>
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<tr>
<td>Africa</td>
<td>Boribo, Ngowe, Apple, Early Gold, Nimrod, Malindi, Kensington,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mabroka</td>
<td></td>
</tr>
<tr>
<td>Florida</td>
<td>Irwin, Tommy Atkins, Smith, Kent, Palmer, Sensation, Keitt,</td>
<td></td>
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<td></td>
<td>Haden</td>
<td></td>
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<tr>
<td>West Indies</td>
<td>Julie, Peter</td>
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</tr>
</tbody>
</table>

1 Source: Subramanyam et al., 1975.
2.2 **BOTANICAL ASPECTS**

*Mangifera indica* L., belongs to the dicotyledenous family Anacardiaceae which consists of sixty-four genera. The tree itself is evergreen and may attain a size of fifty to sixty feet. The mango fruit is a laterally compressed, fleshy drupe. Its colour varies between green through yellow to red. The shape varies from rounded to ovate-oblong with the length varying from two to thirty centimetres in different varieties and the weight from several grams to more than a kilogram. The mesocarp provides the edible pulp, which is firm, containing a sweet, well-flavoured juice. In the mango, the endocarp develops into a tough leathery covering of the seed and is termed the husk. The seed is exalbuminous (Hulme, 1971). Fig. 1 gives details of the shape and specific names of the various outward physical features of the fruit.
source: Hulme, 1971
2.3 PHYSIOLOGY OF RIPENING

Mangoes are harvested usually at the mature-green stage and are then allowed to ripen under ambient conditions (25-30°C/85% R.H.). Fruits are not allowed to ripen on the tree for two reasons:

i) because the majority of the fruits drop from the tree before they are ripe enough for consumption; and

ii) because tree-ripe fruits are inferior in taste and aroma to fruits that ripen after harvest, and their keeping quality is reduced.

The physiology of ripening involves numerous metabolic activities resulting in fruits of acceptable quality. Of these physiological activities, changes in carbohydrates and acids (to give the desired sugar-to-acid ratio), development of colour and flavour characteristics of the variety for consumer appeal, and softening of the texture for acceptable quality are of prime importance. All these biochemical changes take place within a short period of ten to fourteen days at ambient temperature, depending on the variety and stage of maturity at harvest (Subramanyam et al., 1975).

2.3.1 RESPIRATION

After the pioneering work of Kidd and West (1922), the importance of fruit respiration in determining storage behaviour of fleshy fruits has received considerable attention. Work done on Neelum mangoes shows that the respiratory rate is closely related to ripening (Banerjee et al., 1934). Leley et al. (1943), working with Alphonso mangoes, noted a climacteric rise
in respiration at the commencement of ripening. The maximum rate of respiration occurred when the fruits were still hard and green (2 to 5 days) or were just beginning to break colour. The fruits were fully ripe after 9 days. During this latter period of ripening the rate of respiration decreased.

Krishnamurthy and Subramanyam (1973), have indicated the following sequence of events based on observable changes during respiration: (i) a pre-climacteric phase lasting for 3 days when the fruits are green and firm and carbon dioxide release is at a low rate; (ii) a climacteric rise extending up to 6 days when a sudden spurt in carbon dioxide production is observed and the fruits remain green and firm and (iii) a climacteric peak occurring between 6 and 10 days after harvest marked by a peak in carbon dioxide release. The fruits at this stage tend to break colour, become soft, and develop an odour characteristic of the variety. This is followed by stage (iv), a post-climacteric phase, lasting from 10 to 14 days, when carbon dioxide release shows a sudden decreasing trend; the fruit develops an attractive colour and odour and is soft and edible-ripe. After this stage, senescence of the fruit sets in, and the fruit is susceptible to microbial infection resulting in decay of the fruit.

As the process releases a large amount of energy, the respiratory climacteric during ripening of the fruit has a great impact on storage life. For the purpose of storage at low temperature, the amount of energy released during ripening is calculated from the respiration rate of the fruit. Physiological losses in weight indicate the total moisture lost during ripening and storage, which results in desiccation and a shrivelled appearance of the fruit. The marketable quality of the fruit also depends on this factor to a great extent. Loss of moisture is greater in immature fruits than in fruits of optimum maturity. This physiological loss is essentially due to transpiration and respiration (Krishnamurthy and Subramanyam, 1973).
2.3.2 THE ROLE OF ETHYLENE

Ethylene is a fruit ripening hormone. Burg and Burg (1962), working with Kent and Haden mangoes noted that these mangoes had a normal pattern of ethylene evolution which coincided with the respiratory peak. Mattoo and Modi (1969) have shown that ethylene promoted the activities of the enzymes catalase, peroxidase and amylase in the slices prepared from pre-climacteric mango.

Ethylene treatment resulted in softening of the slices and appreciable change in colour from white to yellow, suggesting the appearance of symptoms characteristic of ripening (Mattoo, 1969).

A three-fold increase (from 18 μl/hr/g to 50 μl/hr/g) in ethylene production was observed in ripening mango slices (Mattoo and Modi, 1967) in the presence of methionine (3 to 7 μ moles), suggesting that methionine may be a precursor of ethylene in mangoes possibly with 4-methyl-mercapto-2-oxobutyric acid as an intermediate as suggested for tomatoes (Eskin et al., 1971) and shown in Fig. 2.
Methionine  →  4-methylmercapto-2-oxobutyric acid

\[
\text{CH}_3\text{CH}_2\text{CH}_2\text{S}\text{CHNH}_2\text{COOH} \quad \rightarrow \quad \text{CH}_3\text{CH}_2\text{CH}_2\text{S}\text{CH}_2\text{CH}_2\text{C}=\text{O}\text{COOH}
\]
2.4 CHEMICAL CONSTITUENTS OF MANGO - CHANGES DURING RIPENING AND STORAGE

During post-harvest storage of mangoes, several chemical changes take place as the fruit ripens. Changes that affect organoleptic and nutritional quality of the mango fruit are dealt with below. A summary of some of the more important changes during ripening is given in Table 3.

2.4.1 SUGARS

Sugars form a high proportion of the soluble solids in ripe mangoes. After picking, the sugar content of the mango fruit increases at the expense of starch already present. The principal free sugars present in the mango fruit are glucose, fructose and sucrose, while xylose and arabinose have also been detected in smaller quantities during different stages of fruit ripening (Siddappa and Bhatia, 1954; Sarkar, 1963). The presence of d-manno-heptulose and d-altro-heptulose in Hawaiian mangoes was established by Ogata et al. (1972).

During ripening glucose and fructose (the reducing sugars) remain steady while sucrose increases. The increase in sucrose content is mainly attributed to the breakdown of starch with the result that starch is virtually absent at the edible-ripe stage (Lakshminarayana, 1980).

It has been suggested that the sweetness of ripe mango is largely contributed by sucrose (Lakshminarayana et al., 1970; Lakshminarayana and Vazquez-Salinas, 1978; Wahab and Khan, 1954).
## TABLE 3

<table>
<thead>
<tr>
<th>CONSTITUENT</th>
<th>UNRIPE</th>
<th>PARTLY RIPE</th>
<th>RIPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total sugars (g%)</td>
<td>6.1</td>
<td>10.9</td>
<td>17.1</td>
</tr>
<tr>
<td>Sucrose (g%)</td>
<td>2.4 (+1.6)</td>
<td>5.5 (+4.0)</td>
<td>8.0 (+3.6)</td>
</tr>
<tr>
<td>Glucose (g%)</td>
<td>1.6 (+0.66)</td>
<td>2.2 (+0.4)</td>
<td>3.5 (+1.12)</td>
</tr>
<tr>
<td>Fructose (g%)</td>
<td>1.97 (+1.4)</td>
<td>3.04 (+1.6)</td>
<td>5.6 (+3.1)</td>
</tr>
<tr>
<td>Acidity (g%)</td>
<td>4.1 (+0.69)</td>
<td>3.73 (+0.1)</td>
<td>0.293 (+0.17)</td>
</tr>
<tr>
<td>Ascorbic acid (g%)</td>
<td>0.25</td>
<td>0.090</td>
<td>0.100</td>
</tr>
<tr>
<td>Carotene (µg %)</td>
<td>488</td>
<td>N.D.</td>
<td>3520</td>
</tr>
</tbody>
</table>

N.D. = Not determined

1 Source: Pantastico (1975).
2.4.2 ORGANIC ACIDS

The nature of the organic acids in mango has received little investigation. The acidity of the fruit is expressed in terms of citric or malic acid, since they are the main accumulated free organic acids contributing to the acidity of the fruit (Jain et al., 1959).

The acid content varies from 4 to 5% in the green fruit to 0.5 to 1.0% in the ripe fruit (Subramanyam et al., 1975). Cheema et al. (1954) observed a correlation between the acid content of green fruit and the length of storage life, the latter being shorter in fruits with lower acidity.

Wardlaw and Leonard (1936) observed that acidity in general, decreased during storage. Cool stored mangoes (10°C) showed a decline in total titratable acidity from 3.08% to 0.6%, the latter being higher than 0.1% acid in the normally ripe fruit. As a result the fruits were sour to taste and the sugar:acid ratio was less than in fruit ripened at room temperature (Krishnamurthy and Subramanyam, 1973). The reduction of acidity during ripening plays an important role in the acid:sugar balance and consequently in influencing the taste and flavour of the fruit.

2.4.3 PIGMENTS

The colour of mango fruit is essentially due to carotenoids and chlorophyll (Subramanyam et al., 1975). Fruits of some cultivars are externally green throughout development (Var. Bombay Green) or turn greenish-yellow (var. Mulgoa, and Totapuri) or yellow (var. Alphonso and Dashehari) during development. As these fruits ripen they become more intense in their respective external colours. The significant external colour changes during ripening are the disappearance of chlorophyll, the apparent increase of
anthocyanin pigments and a significant increase of total carotenoids and \( \beta \)-carotene (Lakshminarayana, 1980).

Yamamoto et al. (1932) isolated carotenes from mango fruit and concluded that they are a mixture of \( \alpha \) and \( \beta \)-carotenes.

Jungalwala and Cama (1963) characterised the carotenoids of mango and studied their quantitative distribution. About 60% of the total carotenoids consist of \( \beta \)-carotene. According to Chowdhury (1950), the total carotenoid and individual pigments rise rapidly to a maximum and then fall. At temperatures above 36°C, these changes are accelerated without affecting the maximum value for carotene. Exposure to U.V. light increases the carotenoid content during ripening period.

Mattoo et al. (1968) concluded that carotenogenesis in the ripe fruit is regulated by phosphatase which seems to dephosphorylate the intermediates of the carotenogenic pathway.

Carotene constituted the major carotenoid pigment in unripe (37%) and fully ripe (50%) mangoes. Total carotenoids showed a twenty-fold increase and \( \beta \)-carotene a ten-fold increase during ripening of Alphonso and pairi mangoes. The ratio of these two varied widely, depending on the variety, soil condition, maturity and date of harvest in the same orchard (Krishnamurthy and Subramanyam, 1970).

Srivastava et al. (1962) reported that inhibition of respiration greatly influenced the biosynthesis of carotenoids by way of a proportional decrease in the rate of carotenoid formation in mangoes during ripening. With the increase in respiration rates, there was an enhanced development of carotenoid pigments and degradation of chlorophyll. Thus the use of low temperatures and skin coatings could significantly affect the rate of carotenoid synthesis during storage.
2.4.4 VITAMINS

Mango is probably the richest natural source of carotene and a good source of vitamin C.

Singh (1960) lists the vitamin C content of more than 50 varieties of the fruit when ripe. The values vary between 13 and 178 mg per 100 g fresh pulp. More recently, Iguina de George et al. (1969), in a study of mango varieties grown in Puerto Rico, gave a range of vitamin C content from 6 to 63 mg per 100 g for fully grown fruits, the highest value being recorded for the Julie variety.

Of the important commercial varieties, Langra is the richest in vitamin C and values for the edible portion of the ripe fruit reported from Pakistan and India are 200 and 176 mg per 100 g respectively. Vitamin C content of mangoes varies not only with variety but also with the stage of maturity and size, the smaller fruits being richer than the larger fruits (Jain, 1961).

Work done by Thomas and Oke (1980) shows that the peel of mango contained two to six times as much vitamin C as the pulp, depending on the cultivars, the maximum being 590 mg per 100 g fresh peel in the cultivar Langra.

The mango is also rich in carotene and other carotenoid pigments capable of being converted by the human body into vitamin A. Again Singh (1960) lists the vitamin A equivalent (I.U.) of a number of important mango cultivars. These range between 1000 I.U. and 6000 I.U./100 g fresh weight.*

Iguina de George et al. (1969) examined the β-carotene content of 30 varieties of mangoes grown in Puerto Rico. They divided the varieties into 3 categories based on three ranges of β-carotene expressed in terms of I.U. namely, 400-2500 I.U., 2500-4000 I.U. and 5000 I.U.-8000 I.U. per 100 g fresh weight. The Keitt, Kent and Haden varieties fell into the first category.

* 100 INTERNATIONAL UNITS (IU) OF VITAMIN C = 5 mg ASCORBIC ACID
the Julie into the second category while 7 varieties including Zill, occupied the third category with Carrie (7900 I.U.) occupying the premier place.

2.4.5 CELL WALL CONSTITUENTS

It is generally accepted that softening and textural changes occurring during ripening are associated with pectic changes. The principal enzymes associated with the solubilization of protopectin are the pectolytic enzymes, namely pectinesterase and polygalacturonase. Pectinesterase de-esterifies the methyl esters, freeing carboxyl groups, whereas polygalacturonase splits the polygalacturonides into smaller units and finally to d-galacturonic acid residues.

According to Subramanyam et al. (1975), generally there is a decrease in the molecular size and esterification of pectin during ripening of mango fruits.

Lakshminarayana et al. (1970) demonstrated that celluloses and hemicelluloses (considered as alcohol-insoluble materials other than starch) remained constant in the Alphonso mango throughout its growth period, but towards physiological maturity it showed a slight build-up in the flesh due to swelling of the fruit (cell enlargement). Rolz et al. (1972) studied the overall changes in the quantity of cell wall material during ripening. They observed a gradual decline during the ripening process which resulted in the softening of the fruit (var. Mamey). The uronic and carbonyl contents of the water-soluble fraction of pectin increased to a maximum when the fruit was ripe and subsequently decreased when the fruit was over-ripe.

Similar studies by Mizuta and Subramanyam (1973) on Alphonso and Pairi mangoes showed that high and low methoxy pectins increased
continuously up to a certain period after the onset of ripening. A concomitant reduction in protopectins also occurred. The total pectin of both varieties increased continuously during ripening. Total pectin was always higher in the Alphonso than in the Pairi. The hemicellulose and the cellulose contents did not show appreciable changes during ripening in these and, therefore, appear to have insignificant roles in the textural changes during ripening.

Mango polysaccharides were determined by Nour and McKay (1975) from alcohol-insoluble solids obtained from Alphonso mango of Sudanese origin. They extracted the alcohol-insoluble solids in hot propan-2-ol. On analysis of the dried powder they found 9.85% moisture, 4.87% ash, 17.85% crude fibre, 18.63% crude protein and 3.93% lignin. They classified the polysaccharides of mango into three categories: (i) water-soluble polysaccharides (16.47%) which were composed of starch 1.87%, glucan 3.13%, polyuronide 6.96% and non-precipitable 4.52%; (ii) acid-soluble polysaccharides (21.07%) which were composed of glucan 2.24% and polyuronide 18.83%; and (iii) alkali (dilute) soluble polysaccharides (0.67%). Hydrolysis of the purified pectin fractions (polyuronides) from the alcohol-insoluble solids revealed the presence of neutral sugars, such as galactose, arabinose and xylose. These formed part of the acidic macromolecules.

2.4.6 ASTRINGENTS

Phenolic compounds make an important contribution to the flavour of mango fruit because of their astringency.

Lakshminarayana et al. (1970) investigated the polyphenolic substances of the Alphonso mango during growth. The young fruit, in the initial stages, had a high polyphenol content and consequently, was highly astringent. There was a gradual reduction
up to the eighth week after fruit-set, after which the polyphenolic content remained steady. The phenolic constituents of the peel were quantitatively higher than in the flesh. There was no relationship between polyphenol content of the fruit and the hardening of the mango stone during fruit development.

Soule and Harding (1956) made a quantitative study of total polyphenol content (tannins) in the fruit of 6 Florida mango cultivars (Haden, Irwin, Keitt, Kent, Sensation and Zill) with the object of establishing harvest maturity. They all varied from 31 to 76 mg in the hard fruit (at harvest) and 31 to 75 mg in the ripe fruit. They did not observe any consistency in the fruit with regard to the tannin content during ripening. It was generally observed that smaller fruit had a slightly higher tannin content than larger fruit.

El-Ansari et al. (1969) made a qualitative study of the polyphenolic components of the Rumani mango (a seedling variety) at tender, mature and ripe stages. They found gallic acid, m-digallic acid, galactotannin, quercetin, isoquercetin, mangiferin and ellagic acid at the tender stages. They observed a slight degree of polymerization of the digallic acid during maturity and the disappearance of quercetin and isoquercetin during ripening (Table 4).

The same authors (El-Ansari et al., 1971) later confirmed their previous findings and, in addition, reported that gallo-tannin, a toxic component, occurred in fairly large quantities in the unripe fruit.

Mahadeviah et al. (1975) found gallic acid and ellagic acid in the peel of Alphonso, Rasputi and Baganpali mangoes. Pulp obtained from unpeeled mangoes produced feathering of tin cans during prolonged storage. This was due to the presence of gallic acid in the peel which acted as an accelerator of tin corrosion. Formation of a bluish-black complex with the iron content of the tin can was evident. They also identified in these mangoes the
<table>
<thead>
<tr>
<th>Stage</th>
<th>Polyphenolic Components Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>Gallic acid, m-digallic acid, gallotannin, quercetin, isoquercetin, mangiferin, ellagic acid.</td>
</tr>
<tr>
<td>Mature</td>
<td>Gallic acid, m-digallic acid, m-trigallic acid, gallotannin, quercetin, isoquercetin, mangiferin, ellagic acid.</td>
</tr>
<tr>
<td>Ripe</td>
<td>Gallic acid, m-digallic acid, m-trigallic acid, gallotannin, mangiferin and ellagic acid.</td>
</tr>
</tbody>
</table>

1 Source: El-Ansari et al., 1969.
presence of leucopetunidin and leucopelargonidin as peel pro-anthocyanidins which did not participate in accelerating corrosion.

2.4.7 ODORIFEROUS COMPOUNDS

Soule and Harding (1957) pointed out that maximum flavour development was noted on the sixth day after harvest in Florida mangoes. However, this is a relative point as the speed of ripening and flavour development depends on the stage of maturity at harvest and the conditions of storage and ripening.

Pattabhiraman et al. (1969) using the flesh pulp of Alphonso mango studied the flavour constituents. The pulp was extracted with different organic solvents to determine the most efficient solvent. Odoriferous components of the pulp were also separated by steam distillation and with organic solvents under atmospheric and reduced pressures. When concentrates were obtained, they were subjected to column (with ether and chloroform as solvents), thin layer and gas-liquid chromatography for the separation of the odoriferous ingredients.

Of the different solvents tested for extraction, chloroform, peroxide free diethyl ether and ethyl alcohol appeared to appreciably extract the odour principles. Removal of solvents under vacuum at 40° to 60°C did not affect the odoriferous principles, although the alcohol extract under vacuum distillation at 50° to 55°C yielded a syrupy residue with a cooked flavour. Evaporation of solvents on a boiling water bath resulted in a total loss of the odour. These results indicated that the odoriferous principles in mango were thermolabile.

The problems encountered in extraction of odour concentrates in previous work was later solved by Pattabhiraman et al. (1969) using an all-glass "cyclone separator". Mango pulp was made into a slurry with specified amounts of water and passed through a steam-heated jacket. The steam carrying the odoriferous ingredients was
condensed in cooling traps. The aqueous extracts were combined and extracted with chloroform to give the characteristic odour of mango. The odour concentrates, free of chloroform, were subjected to U.V., I.R. and N.M.R. Spectroscopy, and gas-liquid chromatography. After close examination of all results they concluded that mango flavour was composed of simple components of ester and carbonyl types.

Hunter et al. (1974) using more advanced techniques identified 41 compounds in canned Alphonso mango puree. Alphonso mango is known to retain most of its flavour and texture during processing. Of the 41 compounds reported, 9 were hydrocarbons, 8 esters, 6 alcohols and 8 lactones. Of the remaining 10, 4 were ketones and 2 aldehydes (see Table 5).

Using high vacuum distillation techniques, Bandyopadhyay et al. (1973) and Gholap and Bandyopadhyay (1975, 1976) studied the aromatic principles of Langra mango and compared them with the fresh pulp essence of Alphonso mango. Using the sniff test for the separated components, they observed distinct differences between the aroma profiles of these mango cultivars. Langra essence consisted of 21 components. Some notes, like green mango, estery, burnt sugar and soily notes were common to both cultivars, whereas Langra had more soily notes and, in addition, had camphory, peach-like and woody notes. Alphonso had the unique almond and coconut-like notes that were absent in Langra. It is therefore, quite possible that similar notes observed in both cultivars were due to the occurrence of similar components. They concluded that a combination of several odoriferous components in proper concentrations, resulted in the characteristic aroma of the mango fruit, thus confirming the views of Hunter et al. (1974). The missing aroma notes experienced in the synthetic mango essence were attributed to the absence of specific components.
### TABLE 5  COMPOUNDS IDENTIFIED IN ALPHONSO MANGO EXTRACT

<table>
<thead>
<tr>
<th>Compound</th>
<th>Basis for identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbons</td>
<td></td>
</tr>
<tr>
<td>Cyclopentane</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Myrcene</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Limonene</td>
<td>MS, GC</td>
</tr>
<tr>
<td>cis-Ocimene</td>
<td>MS, GC</td>
</tr>
<tr>
<td>trans-Ocimene</td>
<td>MS, GC</td>
</tr>
<tr>
<td>cis-Alloocimene</td>
<td>MS, GC</td>
</tr>
<tr>
<td>trans-Alloocimene</td>
<td>MS, GC</td>
</tr>
<tr>
<td>β-Caryophyllene</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Humulene</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Esters</td>
<td></td>
</tr>
<tr>
<td>Ethylacetate</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Methylpyruvate</td>
<td>MS, GC</td>
</tr>
<tr>
<td>n-Butylbutyrate</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Isobutylbutyrate</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Isoamylbutyrate</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Ethyldecanoate</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Ethyllaurate</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Alcohols</td>
<td></td>
</tr>
<tr>
<td>n-Butanol</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Isoamylalcohol</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Linalool</td>
<td>MS, GC</td>
</tr>
<tr>
<td>α-Terpineol</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Terpinen-4-ol</td>
<td>MS, GC</td>
</tr>
<tr>
<td>2-Phenylethanol</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Lactones</td>
<td></td>
</tr>
<tr>
<td>Butyrulactone</td>
<td>MS, GC, IR</td>
</tr>
<tr>
<td>α-Methylbutyrolactone</td>
<td>MS, GC, IR</td>
</tr>
<tr>
<td>Y-Hexalactone</td>
<td>MS, GC, IR</td>
</tr>
<tr>
<td>Y-Heptalactone</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Y-Octalactone</td>
<td>MS, GC, IR</td>
</tr>
<tr>
<td>6-Octalactone</td>
<td>MS, GC</td>
</tr>
<tr>
<td>8-Octalactone</td>
<td>MS, GC</td>
</tr>
<tr>
<td>6-Nonalactone</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Y-Decalactone</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Others</td>
<td></td>
</tr>
<tr>
<td>Acetoin</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>MS, GC</td>
</tr>
<tr>
<td>Furfural</td>
<td>MS, GC</td>
</tr>
<tr>
<td>2-Acetylfuran</td>
<td>MS, GC</td>
</tr>
<tr>
<td>2,5-Dimethyl-2-H-furan-3-one</td>
<td>MS, GC, IR</td>
</tr>
<tr>
<td>5-Methylfurfural</td>
<td>MS, GC</td>
</tr>
<tr>
<td>2,5-Dimethyl-4-methoxy-2-H-furan-3-one</td>
<td>MS, GC, IR</td>
</tr>
<tr>
<td>β-Ionone</td>
<td>MS, GC</td>
</tr>
<tr>
<td>cis-Linalool oxide (5 membered)</td>
<td>MS, GC</td>
</tr>
<tr>
<td>trans-Linalool oxide (5 membered)</td>
<td>MS, GC</td>
</tr>
</tbody>
</table>


2. MS-Mass Spectroscopy, GC-Gas Chromatography, IR-Infrared Spectroscopy.
2.5 STORAGE AND TRANSPORT

Considerable efforts have been devoted over a number of years to improve storage conditions and transport facilities for the promotion of this exotic tropical fruit as an export commodity. Storage diseases and damage during transit are amongst the major factors responsible for restricting its export potential.

2.5.1 STORAGE DISEASES AND DISORDERS

Mango fruit, being perishable, undergoes heavy losses during handling, transportation and storage. Fungi, bacteria and physiological factors in the fruit tissue cause various diseases and disorders of the mango during storage. Fruit rot diseases are caused mainly by fungi. A summary of storage diseases of mango is given in Table 6.

2.5.1.1 ANTHRACNOSE

The fungus *Colletotrichum gloeosporioides* Penz is the cause of anthracnose, the most serious fruit-rot of the mango. This disease is widely prevalent in all the mango growing regions of the world.

Black spots, which later become sunken, develop on the fruit shortly after it is ripe, or even before in some instances. Later the spots coalesce and in a few days at tropical temperatures the whole fruit is involved. The acervuli and spores of the fungus develop as pinkish masses on the sunken spots. The spots are often concentrated at the stem end and sometimes in stripes down the sides of the fruit, suggesting that the spores of the fungus are distributed in drops of water, which, running down the stalk of the fruit, collect at the stem-end and finally run down its sides leaving a deposit of spores (Baker, 1938). The severity
### TABLE 6

<table>
<thead>
<tr>
<th>Type of spoilage</th>
<th>Decay percentage</th>
<th>Organisms or causes responsible for decay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem-end rot</td>
<td>15-20</td>
<td>Gloeosporium mangiferae P. Henn</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Botryodiplodia theobromae Pat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diplodia natalensis Pole-Evans</td>
</tr>
<tr>
<td>Anthracnose</td>
<td>10-15</td>
<td>Colletotrichum gloeosporiodes Penz</td>
</tr>
<tr>
<td>Lateral rot</td>
<td>3-5</td>
<td>Aspergillus niger van Teigh</td>
</tr>
<tr>
<td>Tip rot</td>
<td>1-2</td>
<td>Phomopsis sp.</td>
</tr>
<tr>
<td>Sooty mold</td>
<td>50-60 in coastal areas</td>
<td>Meliola mangiferae Earle</td>
</tr>
<tr>
<td>Soft rot</td>
<td>3-5</td>
<td>Bacillus carotovonous Patel</td>
</tr>
<tr>
<td>Black spot</td>
<td>3-5</td>
<td>Pseudomonas mangiferas indicae Patel</td>
</tr>
<tr>
<td>Spongy tissue</td>
<td>35-55 (in Alphonso)</td>
<td>Physiological; causes not known</td>
</tr>
<tr>
<td>Black tip</td>
<td>10-15</td>
<td>Physiological, brick kiln contamination</td>
</tr>
<tr>
<td>Soft nose</td>
<td>10-15</td>
<td>Calcium deficiency</td>
</tr>
</tbody>
</table>

1 Source: Subramanyam et al., 1975.
of the injury depends mostly on the humidity of the atmosphere. Most of the infection takes place during the blossoming period and remains as latent infection. These latent infections become active and serve as centres of decay when the fruit approaches maturity (Simmonds, 1940, 1965).

During ripening these spots develop rapidly, causing considerable loss in quality during transit and storage.

2.5.1.2 ASPERGILLUS ROT

This rot is caused by the fungus *Aspergillus niger* van Tiegh. The disease usually appears at the stalk-end of the fruit and is quite distinct from rots caused by other organisms. At first it appears as a light brown circular patch. The lesion grows in a regular manner and forms a large circular spot encircling the stalk. After three or four days the infected region becomes sunken and at an advanced stage it becomes shrivelled. The rot is soft in nature. Besides causing stalk-end rot it also causes lateral rot and tip-end rot (Srivastava et al., 1965).

2.5.1.3 STEM-END ROT

This condition is caused by the organism *Diplodia natalensis* P. Evans (Srivastava, 1972). The disease manifests itself only in the ripe mango. In the initial stage, the epicarp darkens around the base of the pedicel. Later, the affected area enlarges to form a circular, brownish-black patch which extends rapidly within two to three days in a humid atmosphere. Fruits without pedicels are more susceptible to disease than those with pedicels.

2.5.1.4 BACTERIAL-ROT

Several pathogenic bacteria have been implicated in bacterial
rot of stored mangoes. Fruits infected with the organism *Pseudomonas mangifera indicae* sp. nov., show deep, longitudinal cracks with a heavy, gummy exudation (Patel et al., 1948). Another bacterial soft-rot disease is caused by *Bacterium caratovorum* resulting in softened depressed areas light brown in colour (Patel and Padhye, 1948).

2.5.1.5 **BLACK-TIP**

Black-tip necrosis is prevalent in India and Florida. Orchards near brick kilns suffer heavy losses. The first symptoms of the disease is the appearance of a small etiolated area at the distal end of the fruit after three to four days of fruit setting. This area gradually increases in size, and the tip becomes necrotic, often exposing the stone of the fruit as a result of disintegration of outer tissues. Affected fruits fail to mature properly, and the tip becomes hard and black (Das Gupta et al., 1955; Das Gupta, 1958).

2.5.1.6 **INTERNAL BREAKDOWN**

This physiological disorder has been reported for several varieties of mangoes. "Soft nose", a physiological disorder has been reported by Young (1960). The symptoms are the breakdown of the flesh on the ventral side and towards the apex in the fruit while it is still on the tree.

In Haden mango there is yellowing of the green skin at the apex, and the area becomes soft. In Alphonso mango, "Internal breakdown" has been reported by Subramanyam et al. (1971). The breakdown tissue is characterised by its pale yellow colour, the tissue is soft or spongy, with or without an off-flavour. A recent
survey regarding the prevalence of this disorder indicated that 25 to 30% of Alphonso mangoes from different areas are subject to this disorder. According to Lakshminarayana (1980) this "physiological ripening disorder" might be an instance of fruit harvested beyond the stage of physiological maturity.

2.5.1.7 CHILL INJURY

Studies on the storage of mangoes from different countries have revealed that they are very susceptible to low-temperature injuries, collectively known as chill injuries. Such injuries are characterised by the formation of discoloured, pitted regions on the skin, followed by non-uniform ripening, poor colour and flavour, and higher acidity with lower sugar content. The intensity of the chill injury depends on the storage temperature, length of storage and cultivar (Chatpar et al., 1971; Mattoo and Modi, 1969 Saucedo et al., 1977; Saucedo and Lakshminarayana, 1977).

2.5.2 POST-HARVEST TREATMENTS

Storage of mango has turned out to be a challenging problem. Various methods have been developed to extend the storage life, reduce losses and improve the quality of the mango fruit. These include both physical and chemical methods. It must be borne in mind that the object of storage is not only to prolong the shelf-life of the fruit but also to maintain the organoleptic qualities of the fruit. Some of the more important post-harvest treatments are reviewed below.
2.5.2.1 LOW-TEMPERATURE STORAGE

One of the methods commonly used to extend storage life of fresh fruit is to employ refrigeration. The rationale behind the use of low-temperature for extending the storage life of fruits is based on the premise that maintaining a cool temperature will result in the lowering of respiration rate, which in turn will reduce the rate of metabolic activity, thus slowing down the rate of ripening resulting in extension of storage life.

Krishnamurthy et al. (1963) recommended a temperature range of 7.2°C to 9°C and relative humidity (R.H.) 85 to 90% for all varieties of mango. The use of lower temperatures invariably resulted in chill injury and the fruits failed to ripen normally when removed to room temperature. Work done in this connection at the low-temperature research station at Trinidad (Wardlaw and Leonard, 1936) revealed that most of the commercial varieties were susceptible to low temperature and developed chill injury. Julie and Ceylon varieties harvested at stage B maturity (Wardlaw and Leonard, 1936) could be held at 7°C for 3 to 4 weeks, and the flavour of the ripened fruit was reported to be consistently good. Thompson (1971) examined optimum refrigerated storage conditions for several varieties of mangoes grown in the West Indies. An interaction between minimum temperature tolerance and stage of physiological maturity was noticed. Low-temperature injury occurred on immature fruits, at temperatures below 10°C, but it did not become obvious until temperatures below 5°C. Valmayor (1972) recommended a temperature of 10°C for Carabao and Pico mangoes. Ripe fruits could be stored for 18 to 21 days and freshly picked mature green fruits for 23 to 26 days. Saucedo et al. (1977), investigating the effect of low temperature on storage of Kent mangoes concluded that temperatures below 13°C were critical in the development of chill injury in the Kent mango fruit.
Refrigerated storage prior to ripening reduced the rate of ripening followed by the inhibited formation of sugars, carotenoids and flavour as corroborated by chemical analysis and organoleptic evaluation.

Recent studies by Mann and Singh (1975, 1976) indicate that pre-cooled Langra and Dashehari mangoes could be stored successfully at 7°C and 9°C and 85 to 90% R.H. for 35 to 45 and 25 to 35 days respectively. These fruits, after removal from cool storage, ripened to a satisfactory palatability without affecting the sugar and total soluble solids content. However, they noted a lower carotenoids content in the ripe fruits subsequent to cool storage.

Mattoo and Modi (1969) and Chatpar et al., (1971), studied the cause of chill injury in Alphonso mango and its consequent effect on the chemical composition of the fruit. They found a significant decrease in the sugar content (mainly sucrose), less starch breakdown and less ascorbic acid accumulation (see Table 7) in chill injured fruit. In addition to these changes, there was accumulation of minerals in the chill injured peel. The chill injured fruit showed excess softness during prolonged storage due to pectolytic enzyme activity.
### TABLE 7

<table>
<thead>
<tr>
<th>Stage of fruit</th>
<th>Condition of the tissue</th>
<th>Free Hexose sugars (^3)</th>
<th>Total soluble sugar (^3)</th>
<th>Total Nitrogen</th>
<th>Starch</th>
<th>Ascorbic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unripe</td>
<td>Chill-injured</td>
<td>1.6 ± 0.2</td>
<td>2.1 ± 1.0</td>
<td>0.12 ± 0.01</td>
<td>9.2</td>
<td>0.290</td>
</tr>
<tr>
<td></td>
<td>Healthy</td>
<td>1.9 ± 0.4</td>
<td>3.2 ± 1.2</td>
<td>0.11 ± 0.01</td>
<td>6.0</td>
<td>0.250</td>
</tr>
<tr>
<td>Partly ripe</td>
<td>Chill-injured</td>
<td>4.1 ± 0.3</td>
<td>10.8 ± 3.0</td>
<td>0.18 ± 0.04</td>
<td>Traces</td>
<td>0.112</td>
</tr>
<tr>
<td></td>
<td>Healthy</td>
<td>4.9 ± 0.5</td>
<td>13.0 ± 3.8</td>
<td>0.16 ± 0.05</td>
<td>Traces</td>
<td>0.090</td>
</tr>
<tr>
<td>Ripe</td>
<td>Chill-injured</td>
<td>4.3 ± 1.0</td>
<td>11.2 ± 0.6</td>
<td>0.14 ± 0.02</td>
<td>Traces</td>
<td>0.188</td>
</tr>
<tr>
<td></td>
<td>Healthy</td>
<td>4.3 ± 1.2</td>
<td>13.0 ± 0.4</td>
<td>0.16 ± 0.02</td>
<td>Traces</td>
<td>0.165</td>
</tr>
</tbody>
</table>

2. Results are expressed in g/100 g pulp fresh wt.
3. Mean ± SD.
Thus it is evident from the literature reviewed above that each variety of mango has its own optimum low-temperature for storage and by the same token an optimum ripening temperature.

2.5.2.2 CONTROLLED ATMOSPHERIC STORAGE

Technically controlled atmospheric storage (CA) implies addition or removal of gases resulting in an atmospheric composition substantially different from that of normal air. Thus carbon dioxide (\(\text{CO}_2\)), oxygen (\(\text{O}_2\)), ethylene (\(\text{C}_2\text{H}_4\)), acetylene (\(\text{C}_2\text{H}_2\)), and nitrogen (\(\text{N}_2\)) may be manipulated to attain various gas combinations. In common usage CA refers to increased carbon dioxide (\(\text{CO}_2\)), decreased oxygen (\(\text{O}_2\)) and high nitrogen (\(\text{N}_2\)) levels compared with normal atmosphere (Do and Salunkhe, 1975).

Singh et al. (1937) examined the response of the respiratory system in the mango fruit to alterations in the concentration of oxygen and nitrogen with the view of suggesting CA storage for this fruit. Hatton and Reeder (1965) stored Keitt mangoes at 13°C in different controlled atmospheres for 20, 30 and 40 days. Best results were obtained with controlled atmospheres containing 5% \(\text{O}_2\) plus 5% \(\text{CO}_2\) for 20 days, and according to those authors this was not a significant advantage.

Lakshminarayana and Subramanyam (1970) studied the storage of Alphonso mango fruit in static atmospheres of 5, 10 and 15% \(\text{CO}_2\) concentration in air at 11.1°C and 12.2°C and R.H. 85 to 90% over a period of 32 days. They observed that \(\text{CO}_2\) concentrations in the storage chambers increased beyond their fixed levels due to excess \(\text{CO}_2\) liberation within 4 to 8 days and, subsequently, were uncontrollable. There were indications of \(\text{CO}_2\) injury and fermentative decarboxylation with the formation of aldehyde and alcohol as end-products. Accumulation of these toxic end-products was greater at higher \(\text{CO}_2\) concentrations.
Decarboxylation in fruit under CO₂ atmospheres was independent of oxygen uptake as evidenced by a very low oxygen content in the storage chambers. Chemical analysis of fruit after 32 days storage indicated a significant reduction in the formation of sugars and carotenoids. Subsequently, Manzo and Lakhshminarayana (1972) studied the CA storage of Alphonso mango using mixtures of CO₂-O₂ (5% CO₂ and 2% O₂; 8% CO₂ and 3% O₂; 10% CO₂ and 5% O₂) in a continuous gas flow system at room temperature over 30 days without any significant benefits. Philippine mangoes were stored for 40 days in a storage atmosphere of 5% CO₂ and 5% O₂ at 10°C (Valmayor, 1972). Caribbean mangoes (var. Julie), were stored for 4 weeks in a storage atmosphere of 5% CO₂ and 5% O₂ at 11-12°C/90% R.H. (International Institute of Refrigeration, 1979).

2.5.2.3 HYPOBARIC STORAGE

"Hypobaric" storage or "low pressure" storage consists of placing a commodity in a flowing air stream, substantially saturated (R.H. 80-100%) at a reduced pressure (4-400 mm Hg absolute), and controlled temperature (Burg, 1975). Storage life of mango can be prolonged under subatmospheric air pressure, since this procedure accelerates the escape of ethylene from the fruit tissue and also reduces the oxygen tension in the atmosphere, thereby lowering the sensitivity of the fruit tissue to ethylene action (Burg and Burg, 1966).

Work done by Spalding and Reeder (1977) on Irwin, Kent and Tommy Atkins mangoes indicates that these fruits ripened with less decay and had a higher percentage of acceptable fruits when stored for 3 weeks at 13°C/90-100% R.H., and atmospheric pressure of 76 or 152 mm Hg rather than at normal pressure. Mangoes stored at 152 mg Hg required 3 to 5 days longer to soften after storage when compared to similar fruits stored at 760 mm Hg.
Both CA storage and hypobaric storage have failed to attract the attention of mango exporters due to the inhibitory cost factor. Hence the small advantage gained by storage using these techniques precludes their practical use at this time.

2.5.2.4 IRRADIATION

Since 1960, ionising radiations have been used to reduce spoilage, delay ripening and extend the storage life of mango. This is probably one of the most sophisticated techniques ever used on foods. Earlier workers (Mathur and Lewis, 1961; Hatton et al., 1961; Upadhye and Brewbaker, 1966) used very large doses, varying between 10,000 and 200,000 rads, on mango. Variable results on decay control, inhibition of ripening and extended storage-life were obtained. Dharkar et al. (1966a) obtained better results using lower doses of irradiation (25 K rads) in combination with treatments, such as irradiation under nitrogen (N₂) or carbon dioxide (CO₂) atmospheres with or without skin coatings. The lower values obtained for ascorbic acid, carotenoids and sugars in the irradiated ripe mangoes were attributed to the delay in ripening by 3 days. These authors did not analyse the fruit after 3 days to determine whether irradiated fruit reached the same concentration level of the chemical constituents as found in non-irradiated ripe fruit.

These results did not agree with subsequent observations by Dharkar et al. (1966b) who reported increases in sugar contents in spite of using skin coatings and irradiation under air, N₂ or CO₂ (shown earlier to delay ripening). The same authors observed that exposure of fruit to doses above 75 K rad of gamma rays resulted in radiation injury as manifested by browning of the skin and pulp tissues. Thomas and Janave (1973) noted that the intensity
of browning increased with increasing dose and with a prolonged storage period. On examination they found that non-irradiated fruit had little or no polyphenoloxidase activity, whereas fruits irradiated up to 75 K rad showed monophenoloxidase activity and beyond that dose level, both mono- and diphenoloxidase showed activities. There was a simultaneous reduction in the ascorbic acid content in the irradiated fruit. This was related to the reductive activity of vitamin C towards browning (reduction of orthoquinones to orthophenols). When the ascorbic acid content was depleted in the tissue, browning resulted because of orthoquinone polymerisation. They concluded that the synthesis of the enzyme polyphenoloxidase was induced as a consequence of irradiation.

Dennison and Ahmed (1967) working with Kent mango and using doses of 100, 200 and 300 K rads observed that irradiated fruit was softer than non-irradiated fruit. The former contained higher water-soluble pectin fractions and exhibited higher pectin esterase activity. At a higher dose rate (300 K rads) they observed lower reducing sugar and total sugar content. The effects of gamma radiation were also investigated by Cueves-Ruiz et al. (1972) in 5 mango cultivars grown in Puerto Rico. Irradiation with 75 K rads did not significantly affect ascorbic acid, total carotenoids, carbohydrates and titratable acids. Lower values for these constituents were encountered, however, in irradiated fruit that were once again related to delay in ripening. It is therefore necessary to analyse the irradiated ripe mango to make comparisons, without which it is difficult to draw conclusions.

Sreenivasan et al. (1971) attributed the altered respiratory behaviour of irradiated mangoes to an alternate pattern of metabolism, possibly to the glyoxylate cycle. According to Thomas and Janave (1975), gamma irradiation of Pre-climacteric Alphonso mango
at 25 K rads did not affect the formation of carotenoids. Irradiated ripe fruit had more carotene than xanthophylls, irrespective of storage temperature, when compared to non-irradiated fruit. However, loss of ascorbic acid during ripening was accentuated by irradiation. Thomas and Desai (1976) justified the use of gamma irradiation if judiciously used (at lower dose levels) with combination treatments to induce delayed ripening, and reduce post-harvest decay caused by infection and infestation.

According to Maxie et al. (1971), irradiation holds little promise for perishable commodities with high moisture content. This is based not only on the economics of using irradiation technology but also on consumer resistance to all types of irradiated foodstuffs.

2.5.2.5 HEAT TREATMENT

Pennock and Maldonaldo (1962) using a post-harvest heat treatment (15 minutes hot-water dip at 51-52°C) found that this treatment reduced anthracnose decay in stored mangoes. According to Smoot and Segal (1963), a hot-water dip of mangoes at 54-56°C for 4-5 minutes was most effective in controlling anthracnose decay in Florida mangoes. Hatton and Reeder (1964) confirmed this observation by trials on a commercial scale. According to them, anthracnose was effectively controlled by a 5 minute immersion in water at 55°C. This was true for 8 of 9 varieties selected for treatment.

Hot-water treatment has been reported to enhance surface colour and carotene content of mangoes (Subramanyam and Sebastian, 1970). This effect was more pronounced in fruits of lower maturity (Subramanyam, 1973). There was an overall reduction (from 25% to 5%) in fungal spoilage in heat treated fruits. Perhaps the development of fungal infection is delayed if not eradicated completely.
2.5.2.6 ANTI-MICROBIAL TREATMENT

Various anti-microbial agents have been used to reduce losses during storage and ripening of mangoes without much success. Major losses occur due to anthracnose disease caused by the fungi *Colletotrichum gloeosporioides* Penz. Some degree of success has been reported by Jacobs *et al.* (1973) in controlling post-harvest decay of mangoes caused by anthracnose and soft-brown rot by submerging the fruit immediately after picking, in a suspension of benomyl at 55°C for 5 minutes.

Work done on storage of Keitt mangoes indicates that a hot water dip controlled anthracnose for 3 weeks at 55°C. Benomyl or thiabendazole added to the hot water gave control for 4 weeks. Stem-end rot was not controlled by any of the treatments (Spalding and Reeder, 1972). The control of either decay was not effective when applied at room temperature.

2.5.2.7 SKIN COATINGS

Over the past few years, several wax formulations have been developed based on sugar-cane wax, carnauba wax and microcrystalline paraffin wax, with and without added fungicide and these were tested on a number of mango cultivars grown in India. Treatment with these coatings reduced weight loss but also delayed the development of skin colour, which was not advantageous for immediate marketing (Subramanyam *et al.*, 1975). However, Srivastava *et al.* (1962) claimed that skin coatings of mangoes has brought about drastic changes causing a serious biochemical imbalance within the fruit. Mathur and Srivastava (1955), using mineral oil as a coating, found that coating the entire mango surface resulted in skin injury and breakdown of the fruit.
2.6 PRO-LONG

Since Kidd and West (1922) developed gas storage, efforts have been directed towards developing a material which would coat fruits in such a way that, by natural respiration, an internal gas atmosphere would develop in proportions suitable for short or long-term transportation and storage. Extensive research has been carried out by Lowings and Cutts (1981) to produce an edible coating for some fruits and vegetables which is semi-permeable to $CO_2$ and $O_2$ in such a way that $O_2$ levels within the fruit can be greatly lowered without an equivalent rise in the internal $CO_2$ levels. These workers found that a specific mixture of lipids (i.e. sucrose esters of a group of fatty acids), mixed with a polysaccharide, fulfills these criteria and it has just been introduced to the market under the trade name Pro-long. The basic principles of this material are that when the powdered mixture is dissolved and dispersed in water, applied to certain fruits and vegetables and allowed to dry, it creates a semi-permeable gas barrier which promotes the development of internal gas mixtures which have proved effective in reducing the metabolic rate (and water loss) of a wide range of fruit and vegetables.

Pro-long was developed for use on bananas. Intensive work has been carried out on bananas as these are readily available in much the same physiological state throughout the year. As a result of this, elevated temperature carriage trials have been conducted from the Windward Islands to the U.K. with very encouraging results and further trials are underway to establish the maximum energy saving for refrigeration and reduction in capital cost of new vessels (Lowings and Cutts, 1981).

Pro-long has since been extended to fruits such as limes and avocados. Motlagh (1982) working on Brazilian limes observed that limes treated with Pro-long retained chlorophyll for longer than untreated fruits. The shelf-life of limes coated with Pro-long
was increased in cold store (8-10°C/90-95% R.H.) and under tropical-ambient conditions (20-25°C/90-95% R.H.). Tarimo (1982) working on avocado (var. Fuerte), observed that Pro-long treated fruits had a considerable retardation in weight loss and an appreciable extension in shelf-life.

Side effects of treatment with Pro-long have been found to include a useful reduction in susceptibility to chill-damage in bananas. Another side effect has been found in the creation of resistance to some fungal rots, including Sclerotinia spp. and Rhizopus nigricans Ehr., in apples, pears and plums. Pro-long has not, however, proved effective in its present form on fruits of the Solanaceae.
2.7 AIMS OF THE PRESENT WORK

The mango fruit is presently considered to be a luxury item in most industrialised countries. It is believed that a reduction in price would pave the way for a substantial increase in consumption. One way to reach this goal would be to reduce the costs involved in long-range transportation and distribution of the fruit. Currently, mango exports are by high-cost air-freight or low-temperature sea-freight and the subsequent distribution network employs high-technology storage techniques.

Recently a new and revolutionary method for extending the shelf-life of fresh fruits and vegetables has been developed, which involves the use of an edible coating and is available under the trade name Pro-long (see Sections 2.6 and 3.1.3).

This study was concerned with the following aspects of the use of Pro-long in extending the shelf-life of mango fruit:

A. To establish the optimum Pro-long concentration for use on mango fruit under different conditions of storage.
B. To study the effect of Pro-long on the physico-chemical and organoleptic qualities of mango fruit during storage.
C. To investigate whether Pro-long can reduce the cost of temperature control during long distance transhipment and perhaps obviate entirely the need for cool chain distribution.
3. EXPERIMENTAL

3.1 MATERIALS

3.1.1 MANGO VARIETIES

Variety Julie was used for the major part of this work. It is one of the most successful variety introduced to the West Indies and is known for its excellent flavour, keeping qualities, suitability for transport, early bearing and its ability to produce regular annual crops (Anonymous, 1907). It has an olive-green skin and shows little variation in skin colouration as grown under Trinidad conditions. The fruit is flat sided and when ripe has a sweet flesh, deep orange-yellow in colour with fibreless texture and good mango flavour and a small thin stone adhering to the flesh. One of its less desirable features is its susceptibility to moisture loss and shrivelling (Wardlaw and Leonard, 1936).

Varieties Haden and Ngowe were also used in storage trials. Haden originated at Coconut Grove, Florida, as a seedling of Mulgoba. The fruit is large and plump with an oval shape and a rounded base. The basal sinus is absent and the "nak" depressed. It has a smooth surface with light to deep apricot-yellow colour. The skin is thick and tough. The flesh is yellowish-orange in colour with a firm texture, rich flavour and sweet taste. The fibres are confined close to the oblong seed adhering mainly along the ventral edge (Singh, 1960).

Ngowe is a Kenyan variety. The fruit is large, long and slender with a prominent hook-like "nak" and an attractive yellow to orange colour. The flesh is deep yellow, free from fibres and has a bland flavour (Purseglove, 1972).
Mangoes at the mature-green stage were supplied by Geest Holdings Ltd., in Spalding. The mangoes were graded according to weight, size and shoulder growth (Cheema and Dani, 1934). For each treatment 3 mangoes were selected for weight loss and 2 mangoes were used for physico-chemical analysis each time.

3.1.2 BENOMYL FUNGICIDE

Benomyl (Methyl(1-butylcarbamoyl)-2-benzimidazolcarbamate) is a locally systemic fungicide manufactured by du Pont and available under the trade name Benalate. It is a 2-substituted benzimidazole compound and its structure is shown in Fig. 3.

![Chemical structure of Benomyl](image)

Fig. 3

Benomyl decomposes slowly in water to methyl 2-benzimidazole carbamate which is only slightly less active than benomyl but probably plays a major role in disease control (Eckert, 1975).
3.1.3 PRO-LONG

Pro-long is currently marketed by Tal Chemicals a subsidiary of Tate and Lyle and a patent has already been applied for (Patent Application No. 8022003). It is available as a dry powder consisting of a mixture of sodium carboxymethyl cellulose together with sucrose esters of fatty acids containing a high proportion of saturated acids. It is capable of easy mixture with cold water at the site of application, such as packing plants, stores, or even in the field. The manufacturers claim the compound to be non-phytotoxic, acceptable as a food additive, cheap, acceptable cosmetically after application to produce, tasteless, odourless, and effective in practice.
3.2 METHODS

3.2.1 PRE-TREATMENT WITH BENOMYL FUNGICIDE

Initial storage trials indicated a high incidence of anthracnose disease in Julie mango. A pre-treatment with benomyl was therefore necessitated in order to reduce spoilage during storage as outlined by Jacobs et al. (1973). The mangoes were dipped in a circulating water bath containing 1000 ppm benomyl and maintained at 55°C. The mangoes were totally immersed in the benomyl suspension for 5 minutes. The mangoes were then allowed to dry on absorbent paper and were ready for treatment with Pro-long as outlined below.

3.2.2 TREATMENT WITH PRO-LONG

Suspensions of different concentrations of Pro-long were prepared as follows:

For a 1% suspension (i.e. 10 g Pro-long to 1000 cm³ water), 100 cm³ of cold tap water were placed into a beaker containing 10 g of dried Pro-long material and mixed together for several minutes with the aid of a magnetic stirrer. The mixture was left standing for 10 minutes and then re-stirred for 2 minutes. A further 400 cm³ of water was then added and the mixture stirred to produce a homogeneous mix. To this suspension a further 500 cm³ of water were added making up in total 1000 cm³ of Pro-long. The mixture was stirred and left for a minimum of 2½ hrs for the various components of the material to complex. After this time had elapsed the suspension was re-stirred before use. For other concentrations of Pro-long the appropriate amounts of Pro-long were accurately weighed and the different concentrations made up
Mangoes after treatment with benomyl were individually dipped in Pro-long, ensuring a total covering of the fruit surface in the process. Excess Pro-long was allowed to drain off by placing the mangoes on perforated racks. The mangoes (when dry) were then packed in perforated cardboard boxes (to ensure adequate ventilation) and placed in adjustable temperature/humidity storage cabinets. Two storage conditions were employed:

(i) optimum low-temperature: \((13^\circ C(+2^\circ)/85-95\% \text{ R.H.})\)
(ii) tropical ambient: \((25^\circ C(+2^\circ)/85-95\% \text{ R.H.})\)

3.2.3 MYCOLOGICAL WORK

Diseased mangoes were swabbed with ethanol and the infected tissues were aseptically obtained for cultural work. All cultural work was carried out with potato-dextrose agar (PDA) in petri-dish culture. All cultures were submitted to 12 hr near ultra-violet (black light) irradiation/12 hr dark at \(25^\circ C\) in order to stimulate sporulation whilst avoiding the germicidal wavelengths. Amann's Lactophenol cotton blue mounting and staining medium was used in slide preparation for microscopic examination.

3.2.4 WEIGHT LOSS

Estimations of loss in weight were made by selecting groups of three standard sized fruits for each batch and weighing them at regular intervals during the storage period.

3.2.5 TOTAL SOLUBLE SOLIDS

Mango juice was obtained by pressing fresh pulp through a muslin filter and the total soluble solids content (°Brix) was determined using the Abbe 60° refractometer (Bellingham and

in the same way.
Stanley Ltd.) at 20°C.

3.2.6 TEXTURE

An Instron Universal Testing Machine (Model '1140') was used for measuring texture. A Magness Taylor cylindrical probe (11 mm diameter) was used to puncture a 1 cm thick mango slice. The Instron was set on drive speed: 100 mm/min, chart speed: 100 mm/min and a force range of 50 kg full scale deflection. The read-out recorded on the chart paper gave a reading in kg.

3.2.7 TITRATABLE ACIDITY

Titratable acidity of the mango pulp was determined according to the indicator method outlined by the Association of Official Analytical Chemists (1980).

10 g of fresh mango pulp from a single fruit was accurately weighed into a 200 cm³ homogenising flask. 50 cm³ of distilled water was added and the mixture homogenised for 30 seconds using an Ultra-Turrax homogeniser. A further 50 cm³ of distilled water was added and the mixture homogenised for 30 seconds. The homogenate was transferred to a capped centrifuge tube and centrifuged at 2000 rpm for 3 minutes. Titratable acidity in 10 cm³ of the supernatant of the centrifuged extract was estimated by visual titration against 0.1 M NaOH with Phenolphthalein as indicator and the results expressed in terms of % acidity as citric acid.

3.2.8 VITAMIN C

The vitamin C content in the mango pulp was determined by the 2,6-dichlorophenolindophenol method according to the Association of Official Analytical Chemists (1980).

Approximately 10 g of fresh pulp from a single fruit was accurately weighed into a 200 cm³ homogenising flask. 50 cm³ of 3% metaphosphoric acid-acetic acid reagent was added and the mixture homogenised for 30 seconds using an Ultra-Turrax homogeniser.
A further 50 cm$^3$ of the reagent was added and the mixture homogenised for 30 seconds. The homogenate was transferred to a capped centrifuge tube and centrifuged at 2000 rpm for 3 minutes. The vitamin C content in 10 cm$^3$ of the supernatent of the centrifuged extract was estimated by visual titration against 2,6-dichlorophenolindophenol dye and the results expressed as mg vitamin C/100 g fresh pulp.

3.2.9 SUGAR

DESCENDING PAPER CHROMATOGRAPHY

Sugars extracted from full-ripe mango pulp were separated on Whatman No. 1 paper using ethyl ethanoate:ethanoic acid:water (EtOAc-HOAc-H$_2$O), 14:3:3 (Lewis and Smith, 1967) and detected using silver nitrate-sodium ethoxide (Trevelyan et al., 1950) and a modified p-anisidine technique (Lewis et al., 1972). The identity of sugars was checked by co-chromatography with authentic standards.

QUANTITATIVE ANALYSIS

The sugar content of the mango pulp both before and after inversion was analysed by the Lane-Eynon method (1923) using Fehling's solution with methylene blue as internal indicator. 20-25 g of fresh mango pulp were accurately weighed into a 200 cm$^3$ homogenising flask. The sample was extracted with four 25 cm$^3$ portions of 85% (v/v) hot aqueous ethanol and filtered on a Buchner funnel and the residue on the filter paper was washed with several portions of hot 80% (v/v) ethanol. The combined filtrate and washings were neutralised with small amounts of sodium carbonate and then evaporated to low volume in a rotary film evaporator at 50°C. The concentrated extract was then treated
with a small amount of neutral lead acetate (saturated solution) to remove substances that may interfere with the sugar analysis. The addition of lead acetate was carried out drop-wise until no more precipitate was formed. The well mixed contents were then allowed to stand for 15 minutes with occasional stirring. The excess lead acetate was removed by adding a solution of concentrated potassium oxalate (drop-wise addition) until no more cloudiness was produced upon the addition of the precipitant. The solution was then centrifuged for 15 minutes at 3000 ppm. The aqueous extract was then made up to 200 cm$^3$ with distilled water. Reducing sugar was estimated both before and after inversion and the results expressed in terms of % reducing sugar and % total sugar respectively.

3.2.10 TOTAL CAROTENIODS

The total carotenoid content in the mango pulp was measured as β-carotene using the method developed at the Indian Agricultural Research Institute and outlined by Roy (1973).

5 g of fresh mango pulp was transferred to a pestle. The pigments were extracted with 3:2 petroleum ether (60-80°C): acetone mixture by grinding with dry sand using a glass mortar. The extracts were decanted into a 50 cm$^3$ volumetric flask. 5 extractions were sufficient to extract all the carotenoids. The volume was made up to 50 cm$^3$ and absorbance measured at 450 nm using the Pye Unicam SP 800 UV-Spectrophotometer. The total carotenoid was estimated from the calibration curve shown in Fig. 4 and expressed as μg β-carotene/100 g fresh pulp.
FIG. 4 STANDARD CURVE FOR ESTIMATION OF CAROTENOID CONTENT IN MANGO

ULTRAVIOLET SPECTROPHOTOMETER SP900

CONCENTRATION (µg/50 cm³)

1.0
0.8
0.6
0.4
0.2
0
20 40 60 80 100 120 140 160 180 200 220 240 260 280
(standard β-carotene)
3.2.11 ETHANOL CONTENT

Gas-liquid chromatography was used to quantitate the ethanol content in mango pulp using propanol as an internal standard. Solutions containing 0.5% propanol with 0.2, 0.4, 0.6, 0.8 and 1.0% ethanol in distilled water were prepared to obtain a standard curve (Fig. 5) by plotting the ratio of peak height of ethanol and peak height of propanol against concentration of ethanol having injected 1 μl of each solution into the gas chromatograph.

Mango juice was obtained by pressing fresh mango pulp through several muslin filters and then centrifuging. To a 20 cm$^3$ volumetric flask was added 0.1 cm$^3$ propanol and the flask was then made up to volume with mango juice. 1 μl of this solution was injected directly into the gas chromatograph and the ethanol concentration of the sample was obtained from the standard curve.

Analysis was performed on a Perkin-Elmer F-33 gas chromatograph fitted with a flame-ionisation detector. A metal column packed with 10% carbowax 400 on chromosorb (W.80-100 mesh) AW-DMC5 was used for retention time studies. The chromatograph was run isothermally at 70°C with the carrier gas (nitrogen) flow-rate of 42 cm$^3$/min.

3.2.12 TASTE PANEL WORK

Taste panel work was carried out on sound, full-ripe "control" and Pro-long treated mangoes. 1 cm thick slices of uniform length were served in shallow dishes designated with abstract symbols, e.g. triangle, circle, etc. These symbols were randomly varied. The samples were served to a panel of trained judges consisting of 3 research students, and two members of staff at the college. The criteria used for selection was their performance in preliminary taste panel sessions. The panellists were requested to assess the samples and give scores ranging from 1 to 5. The
FIG. 5 STANDARD CURVE FOR ESTIMATION OF ETHANOL CONTENT IN MANGO

Ethanol content (\%) vs. peak height of ethanol vs. peak height of propanol.
parameters assessed included colour, texture, aroma, taste and presence/absence of off-flavour in the samples. A simple description of the qualities being investigated was included on the taste panel score sheet (see Fig. 6). Water was used to clear the mouth of any carry-over tastes and the tasting was done just before the mid-day meal break. Three samples were presented to the panellists at the same time and no more than three samples were analysed on any one day.
FIG. 6  
TASTE PANEL SCORE SHEET

| PRODUCT | Sample code | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|---------|-------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COLOUR  |             |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| TEXTURE |             |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| MANGO AROMA |           |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| TASTE   |             |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| OFF-FLAVOUR |           |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

Tick the box above each number, the impression which you think best describes the sample.

COLOUR
Sample code

TEXTURE
Sample code

MANGO AROMA
Sample code

TASTE
Sample code

OFF-FLAVOUR
Sample code

Any other comments

PANELLIST

DATE

COLOUR
Sample code

TEXTURE
Sample code

MANGO AROMA
Sample code

TASTE
Sample code

OFF-FLAVOUR
Sample code

not present very strong
4. RESULTS AND DISCUSSION

4.1 GENERAL CONSIDERATIONS

Preliminary storage trials conducted on mango var. Julie indicated the presence of latent fungal infection. In more than 20% of the fruits there was extensive fungal spotting on the skin of the fruits when ripe on areas previously bearing no evidence of infection. Fungal wastage was more severe in the initial batches compared to subsequent batches. This was probably due to the fact that the mangoes received initially were those harvested towards the end of the fruiting season since according to Wardlaw and Leonard (1936), these fruits are more susceptible to fungal diseases.

The use of benomyl as a pre-treatment was found to be effective in reducing incipient surface infections and spoilage during subsequent handling, but had no effect on well established latent infections. Benomyl was therefore used as a pre-treatment in subsequent storage trials.

Two types of Pro-long were available at the commencement of this work: freeze-dried Pro-long and spray-dried Pro-long. Since the latter type was the one to be used commercially, it was decided to carry out storage trials using the spray-dried Pro-long.

2% Pro-long was used in the preliminary storage trials. As the storage period increased, brownish exudation from the stalk ends of the treated fruits was observed. After 20 days, storage trials were discontinued due to extensive fungal spoilage. At this juncture, sound Pro-long treated fruits were found to have a sour taste (0.4% acidity as citric acid was recorded for the pulp) and had a distinct alcoholic odour and off-flavour. This probably resulted from accumulation of CO₂ in the mango pulp, leading to toxic metabolism and causing ripening disorders, and the release
of the brownish exudate from the stalk end. Hence lower concentrations of Pro-long were employed in subsequent storage trials.

The first three batches of mango var. Julie were stored at 13\(^{\circ}\)C/85-95\% R.H. and Pro-long concentrations of 1.0\% and 1.25\% were employed. The results are reported and discussed below.

Initial storage trials on mango var. Julie stored at 25\(^{\circ}\)C/85-95\% R.H. suggested that concentrations below 1.25\% would have to be employed in order to optimise the organoleptic qualities of the fruit. 0.75\% and 1.0\% Pro-long treatments were carried out in subsequent storage trials, as reported below.

Pro-long concentrations below 0.75\% could not be used due to incomplete wetting of the fruit and hence incomplete surface coverage.

It is not clear why the higher Pro-long concentrations are tolerated by mangoes stored at 13\(^{\circ}\)C/85-95\% R.H. and not at 25\(^{\circ}\)C/85-95\% R.H. The difference in the respiratory rates in fruits stored at different temperatures could be one of the factors contributing to this effect.

The two sets of conditions used during storage trials:

(i) Optimum low-temperature: 13\(^{\circ}\)C/85-95\% R.H.
(ii) Tropical ambient: 25\(^{\circ}\)C/85-95\% R.H.

are hence-forth referred to as 13\(^{\circ}\)C storage and 25\(^{\circ}\)C storage respectively.
4.2 MYCOLOGICAL WORK

An attempt was made to isolate and identify the fungi causing disease during the storage of mango var. Julie. Forty isolates from different diseased mangoes were examined. The cultural characteristics changed considerably with time and sub-culturing and it was found more desirable to work with fresh isolates. The most important fungus isolated was Colletotrichum gloeosporiodes state of Glomerella cingulata (Stonem) Spauld and Schenk. Anthracnose disease in Julie mango was caused by this organism, which is a fast growing species. Perithecial, conidial and sterile cultures were obtained. Anthracnose disease is shown in plate 1a.

CULTURAL CHARACTERISTICS

Perithecial form - Aerial mycelium was fine, light grey in colour and of moderate elevation. The substrate was light cream with an olive-grey diffusion. A pinkish tinge was present in some cases. Typical black glomerate perithecial bodies were produced (not embedded in the mycelium).

Conidial and sterile form - Aerial mycelium was fine, of low elevation and fairly dense. From above, the general colour was white to light grey but in some cases it appeared darker corresponding to a dark substratum beneath. In the latter case the margin was pinkish white (see plate 1b).

Conidial description - Oblong, cylindrical spore with obtuse or rounded ends (see plate 1c).

Further confirmation was obtained from the Commonwealth Mycological Institute (CMI): Report from Dr. Mordue on cultures sent to CMI from diseased Julie mango.

Herb IMI numbers: 256795 a
256795 c
PLATE 1a. ANTHRACNOSE DISEASE IN MANGO VAR. JULIE

PLATE 1b. C. GLOEOSPORIOIDES CULTURED ON POTATO DEXTROSE AGAR

PLATE 1c. CONIDIOSPORES OF C. GLOEOSPORIOIDES PHOTOGRAPHED UNDER THE MICROSCOPE (MAG 50x)
4.3 WEIGHT LOSS

Data presented in Table 6 and the graphs in Figs. 7, 8, 9 illustrate the effect of Pro-long on weight loss in mango fruit during storage. For mango var. Julie stored at 13°C there was 12.44% weight loss in the control mangoes after 14 days storage. At this stage the 1.0% and the 1.25% Pro-long treated fruits had a weight loss of 7.26% and 6.89% respectively. The 1.0% and the 1.25% Pro-long treated fruits had weight loss of 12.42% and 12.12% respectively after 25 days storage. Thus the Pro-long treated fruits had a 14 day extended storage period before sustaining an equivalent loss in weight when compared to the control mangoes towards the end of their storage life.

The effect of Pro-long in retarding weight loss in mango var. Julie at the higher temperature of 25°C is shown in Table 8 and Fig. 8. The weight loss in control mangoes after 7 days storage was 8.14%. The 0.75% and the 1.0% Pro-long treated fruits had a weight loss of 5.45% and 4.40% respectively at this stage. The 0.75% and the 1.0% Pro-long treated fruits had a weight loss of 8.10% and 7.57% respectively after 13 days storage. Thus the Pro-long treated fruits had a 6 day extended storage period before sustaining a similar weight loss when compared to the control fruits towards the end of their storage life. Similar trends were noticed in mango var. Haden stored at 25°C as shown in Table 8 and Fig. 9.

When comparing the two varieties, the results show that the variety Julie had sustained greater weight loss than the variety Haden. This was probably due to the difference in fruit size. The fruits of the variety Haden weighed 505 (± 5)g when compared to the variety Julie (250 (± 5)g). Due to the smaller surface area to
### Table 8: Percentage Weight Loss in Mango During Storage

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stored</td>
<td>1% PRO-LONG</td>
<td>1.25% PRO-LONG</td>
</tr>
<tr>
<td>1</td>
<td>0.88(±0.01)</td>
<td>0.48(±0.01)</td>
<td>0.40(±0.01)</td>
</tr>
<tr>
<td>2</td>
<td>2.00(±0.01)</td>
<td>1.28(±0.02)</td>
<td>1.21(±0.01)</td>
</tr>
<tr>
<td>3</td>
<td>3.68(±0.01)</td>
<td>2.43(±0.01)</td>
<td>2.36(±0.01)</td>
</tr>
<tr>
<td>4</td>
<td>4.47(±0.02)</td>
<td>2.86(±0.03)</td>
<td>2.73(±0.02)</td>
</tr>
<tr>
<td>5</td>
<td>5.65(±0.02)</td>
<td>3.50(±0.01)</td>
<td>3.43(±0.01)</td>
</tr>
<tr>
<td>6</td>
<td>6.38(±0.02)</td>
<td>3.78(±0.02)</td>
<td>3.63(±0.03)</td>
</tr>
<tr>
<td>7</td>
<td>7.39(±0.01)</td>
<td>4.26(±0.01)</td>
<td>4.30(±0.01)</td>
</tr>
<tr>
<td>8</td>
<td>9.05(±0.01)</td>
<td>8.94(±0.01)</td>
<td>8.94(±0.01)</td>
</tr>
<tr>
<td>9</td>
<td>9.83(±0.01)</td>
<td>9.83(±0.01)</td>
<td>9.83(±0.01)</td>
</tr>
<tr>
<td>10</td>
<td>10.72(±0.02)</td>
<td>6.30(±0.01)</td>
<td>6.10(±0.01)</td>
</tr>
<tr>
<td>11</td>
<td>11.17(±0.02)</td>
<td>7.02(±0.04)</td>
<td>6.48(±0.03)</td>
</tr>
<tr>
<td>12</td>
<td>12.44(±0.02)</td>
<td>7.26(±0.02)</td>
<td>6.89(±0.03)</td>
</tr>
<tr>
<td>13</td>
<td>9.05(±0.01)</td>
<td>8.94(±0.01)</td>
<td>8.94(±0.01)</td>
</tr>
<tr>
<td>14</td>
<td>10.15(±0.02)</td>
<td>9.98(±0.01)</td>
<td>9.98(±0.01)</td>
</tr>
<tr>
<td>15</td>
<td>10.64(±0.03)</td>
<td>10.50(±0.03)</td>
<td>10.50(±0.03)</td>
</tr>
<tr>
<td>16</td>
<td>11.10(±0.02)</td>
<td>10.96(±0.02)</td>
<td>10.96(±0.02)</td>
</tr>
<tr>
<td>17</td>
<td>12.42(±0.03)</td>
<td>12.12(±0.01)</td>
<td>12.12(±0.01)</td>
</tr>
</tbody>
</table>

1 Data based on 9 replicates (average initial weight of fruit = 267(±2) g).
2 Data based on 9 replicates (average initial weight of fruit = 250(±2) g).
3 Data based on 2 replicates (average initial weight of fruit = 505(±5) g).

Figures given in parenthesis are ±/ values giving an indication of the standard error of the mean.

*Figures given in parenthesis are ±/ values giving an indication of the standard error of the mean.*
FIG. 7  PERCENTAGE WEIGHT LOSS IN MANGO VAR. JULIE STORED AT 13(±2)°C/85-95% R.H.
FIG. 8  PERCENTAGE WEIGHT LOSS IN MANGO VAR. JULIE STORED AT 25(±2)°C/85-95% R.H.
FIG. 9  PERCENTAGE WEIGHT LOSS IN MANGO VAR. HADEN
AT 13(±2)°C/85-95% R.H.
volume ratio in larger fruits when compared to smaller fruits one would expect the latter to lose more weight through transpiration. Also according to Wardlaw and Leonard (1936) the var. Julie is highly susceptible to weight loss and shrivelling when compared to other varieties grown in the West Indies.

Despite the differences in storage conditions, variety and fruit size, the advantage of Pro-long in retarding weight loss in mango has been effectively demonstrated.
4.4 TOTAL SOLUBLE SOLIDS

Total soluble solids measured in °Brix is considered to be an excellent index of ripening in mango fruit during storage. In this investigation there was a substantial increase in the total soluble solids content of the mango pulp during ripening. Slightly lower values in the total soluble solids content were recorded for var. Julie stored at 13°C when compared to fruits of the same variety stored at the higher temperature of 25°C (see Table 9). For mango var. Julie stored at 13°C, the control fruits had a total soluble solids content of 18.8 °Brix at the end of the storage period (13 days). The 1% Pro-long treated fruits had a total soluble solids content of 18.5 °Brix at the end of the storage period (25 days). A much lower °Brix value was recorded for the 1.25% Pro-long treated fruits (17.2 °Brix) at the end of the storage period (see Table 9).

For mango var. Julie stored at 25°C a final °Brix value of 19.5 and 19.2 were recorded for the control and 0.75% Pro-long treated fruits respectively. A much lower final °Brix value was recorded for the 1% Pro-long treated fruits (see Table 9).

Similar trends were noticed in mango var. Haden stored at 25°C (see Table 9). When comparing the varieties Haden and Julie, the former had a much lower total soluble solids content at the end of the storage period. Similarly a lower total sugar content for the var. Haden was recorded when compared to the var. Julie at the end of the storage period (see section 4.8).
### TABLE 2: CHANGES IN THE TOTAL SOLUBLE SOLIDS (°BAIX) CONTENT IN MANGO DURING STORAGE

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STORED CONTROL 1% PRO-LONG 1.25% PRO-LONG</td>
<td>STORED CONTROL 0.75% PRO-LONG 1.0% PRO-LONG</td>
<td>STORED CONTROL 0.75% PRO-LONG 1.0% PRO-LONG</td>
</tr>
<tr>
<td>0</td>
<td>13.5(±0.1) 13.5(±0.1) 13.5(±0.1)</td>
<td>13.5(±0.1) 13.5(±0.1) 13.5(±0.1)</td>
<td>13.5(±0.1) 13.5(±0.1) 13.5(±0.1)</td>
</tr>
<tr>
<td>2</td>
<td>15.0(±0.1) 14.1(±0.1) 13.9(±0.1)</td>
<td>13.0 11.5 10.5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>16.3(±0.1) 15.0(±0.1) 14.7(±0.1)</td>
<td>15.6(±0.1) 14.7(±0.1) 15.3</td>
<td>13.6 12.5</td>
</tr>
<tr>
<td>5</td>
<td>17.5(±0.1) 15.3(±0.05) 15.1(±0.05)</td>
<td>16.4(±0.05) 15.8(±0.1) 15.5</td>
<td>13.8 12.8</td>
</tr>
<tr>
<td>7</td>
<td>17.5(±0.1) 15.3(±0.05) 15.1(±0.05)</td>
<td>16.4(±0.05) 15.8(±0.1) 15.5</td>
<td>13.8 12.8</td>
</tr>
<tr>
<td>9</td>
<td>17.5(±0.1) 15.3(±0.05) 15.1(±0.05)</td>
<td>16.4(±0.05) 15.8(±0.1) 15.5</td>
<td>13.8 12.8</td>
</tr>
<tr>
<td>10</td>
<td>17.5(±0.1) 15.3(±0.05) 15.1(±0.05)</td>
<td>16.4(±0.05) 15.8(±0.1) 15.5</td>
<td>13.8 12.8</td>
</tr>
<tr>
<td>11</td>
<td>17.5(±0.1) 15.3(±0.05) 15.1(±0.05)</td>
<td>16.4(±0.05) 15.8(±0.1) 15.5</td>
<td>13.8 12.8</td>
</tr>
<tr>
<td>13</td>
<td>18.8(±0.1) 17.0(±0.1) 15.8(±0.1)</td>
<td>19.2(±0.1) 17.0(±0.1) 15.0</td>
<td>14.2</td>
</tr>
<tr>
<td>18</td>
<td>17.5(±0.05) 16.5(±0.1)</td>
<td>17.0(±0.1) 15.0</td>
<td>14.2</td>
</tr>
<tr>
<td>21</td>
<td>17.9(±0.05) 16.8(±0.1)</td>
<td>17.0(±0.1) 15.0</td>
<td>14.2</td>
</tr>
<tr>
<td>25</td>
<td>18.5(±0.1) 17.2(±0.1)</td>
<td>17.0(±0.1) 15.0</td>
<td>14.2</td>
</tr>
</tbody>
</table>

1 Data based on 6 replicates.
2 Data based on 2 replicates.

Figures given in parenthesis are off value giving an indication of the standard error of the mean.
4.5 TEXTURE

Results in Table 10 and Figs. 10 and 11 indicate that mango var. Julie stored at 13°C had a firmer texture at the end of the storage period when compared to fruits of the same variety stored at 25°C. 1.25% Pro-long treated mango var. Julie stored at 13°C and 1.0% Pro-long treated mango var. Julie stored at 25°C, registered the highest values for texture at the end of the storage period (see Table 10). This was also reflected in the taste panel work (see section 4.11). Similar trends were noticed in mango var. Haden stored at 25°C.

Comparing the two varieties, results show that the variety Haden had a firmer texture at the beginning of the storage period when compared to the var. Julie, but registered similar values for texture at the end of the storage period (see Table 10 and Fig. 12).
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL</td>
<td>1% PRO-LONG</td>
<td>1.25% PRO-LONG</td>
<td>CONTROL</td>
</tr>
<tr>
<td>0</td>
<td>3.10(±0.04)</td>
<td>3.10(±0.04)</td>
<td>3.10(±0.04)</td>
</tr>
<tr>
<td>1</td>
<td>1.70(±0.02)</td>
<td>2.20(±0.04)</td>
<td>2.40(±0.04)</td>
</tr>
<tr>
<td>2</td>
<td>1.01(±0.04)</td>
<td>2.77(±0.06)</td>
<td>2.66(±0.03)</td>
</tr>
<tr>
<td>3</td>
<td>0.60(±0.02)</td>
<td>0.96(±0.02)</td>
<td>1.68(±0.01)</td>
</tr>
<tr>
<td>4</td>
<td>0.58(±0.01)</td>
<td>0.83(±0.02)</td>
<td>0.25</td>
</tr>
<tr>
<td>5</td>
<td>0.28(±0.01)</td>
<td>0.67(±0.01)</td>
<td>1.04(±0.02)</td>
</tr>
<tr>
<td>6</td>
<td>0.54(±0.01)</td>
<td>0.91(±0.01)</td>
<td>0.41(±0.01)</td>
</tr>
<tr>
<td>7</td>
<td>0.34(±0.01)</td>
<td>0.40(±0.01)</td>
<td>0.28(±0.01)</td>
</tr>
</tbody>
</table>

1 Data based on 6 replicates.
2 Data based on 2 replicates.

Figures given in parenthesis are s.e.m values giving an indication of the standard error of the mean.
FIG. 10  TEXTURAL CHANGES IN MANGO VAR. JULIE STORED AT 13(±2)°C/85-95% R.H.

- ■ Control
- ○ ○ 1 % Pro-long
- △ △ 1.25 % Pro-long

TEXTURE (kg)

NO. DAYS STORED
FIG. 11 TEXTURAL CHANGES IN MANGO VAR. JULIE STORED AT 25(+2)°C/85-95% R.H.
FIG. 12 TEXTURAL CHANGES IN MANGO VAR. HADEN STORED AT
25(±2)°C/85-95% R.H.
4.6 TITRATABLE ACIDITY

Acidity is an important criterion commonly used for assessing the ripening and storage behaviour in mango. The decrease in acid content of mango var. Julie as a result of ripening during storage is given in Tables 11 and 12. The results show a more rapid decrease in acidity in mangoes stored at 25°C when compared to mangoes stored at 13°C as shown in Fig. 13 and 14.

In mango var. Julie stored at 13°C the acid content of the mango pulp dropped from 1.37% to 0.33% after 13 days storage (see Table 11). At this juncture the 1.0% and the 1.25% Pro-long treated fruits had acid contents of 0.7% and 0.92% respectively. After 25 days storage the 1.0% Pro-long treated fruits had an acid content of 0.32% which agreed closely with the controls at the end of the storage period. The 1.25% Pro-long treated fruits had an acid content of 0.73% after 25 days storage. This was reflected in the results obtained from the taste panel assessment (see section 4.11).

For mango var. Julie stored at 25°C, similar trends were observed (see Table 12). The acidity of the control fruits decreased to 0.22% at the end of the storage period (7 days), while the 0.75% and 1% Pro-long treated fruits reached a final acid content of 0.23% and 0.56% respectively after 13 days storage. The higher acid content in the 1% Pro-long treated fruit was also reflected in the taste panel work (see section 4.11). Mango var. Haden stored at 25°C showed similar trends (see Table 13).

Comparing the two varieties, the var. Haden had a lower acid content compared to var. Julie at the end of the storage period.

Fig. 13 and 14 illustrate the relationship between total soluble solids content and acidity in mango during storage. An
<table>
<thead>
<tr>
<th>HU. DAYS STORED</th>
<th>ACIDITY expressed as (% citric acid)</th>
<th>VITAMIN C (mg/100 g pulp)</th>
<th>SUGAR (%) REDUCING</th>
<th>SUGAR (%) TOTAL</th>
<th>TOTAL CAROTENOIDS expressed as µg/β-carotene/100g pulp)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CONTROL 1.0% PRO-LONG 1.25% PRO-LONG</td>
<td>CONTROL 1.0% PRO-LONG 1.25% PRO-LONG</td>
<td>CONTROL 1.0% PRO-LONG 1.25% PRO-LONG</td>
<td>CONTROL 1.0% PRO-LONG 1.25% PRO-LONG</td>
<td>CONTROL 1.0% PRO-LONG 1.25% PRO-LONG</td>
</tr>
<tr>
<td>0</td>
<td>1.37 (±0.11) 1.37 (±0.11) 1.37 (±0.11)</td>
<td>55.0 (±0.3) 55.0 (±0.3) 55.0 (±0.3)</td>
<td>2.3 (±0.1) 2.3 (±0.1) 2.3 (±0.1)</td>
<td>8.5 (±0.3) 8.5 (±0.3) 8.5 (±0.3)</td>
<td>958 (±60) 958 (±60) 958 (±60)</td>
</tr>
<tr>
<td>4</td>
<td>0.94 (±0.02) 0.99 (±0.03) 1.15 (±0.06)</td>
<td>52.5 (±1.0) 54.0 (±0.8) 54.5 (±0.7)</td>
<td>3.2 (±0.2) 2.6 (±0.1) 2.4 (±0.1)</td>
<td>11.3 (±0.3) 10.8 (±0.2) 9.0 (±0.2)</td>
<td>1400 (±150) 1182 (±48) 1014 (±42)</td>
</tr>
<tr>
<td>7</td>
<td>0.78 (±0.01) 0.88 (±0.01) 0.99 (±0.03)</td>
<td>47.5 (±1.0) 51.6 (±1.0) 53.5 (±0.7)</td>
<td>3.3 (±0.1) 3.0 (±0.2) 2.7 (±0.2)</td>
<td>13.1 (±0.2) 11.3 (±0.2) 9.3 (±0.2)</td>
<td>1795 (±105) 1426 (±80) 1112 (±48)</td>
</tr>
<tr>
<td>13</td>
<td>0.33 (±0.01) 0.70 (±0.01) 0.92 (±0.03)</td>
<td>43.1 (±0.6) 49.8 (±0.2) 51.2 (±0.1)</td>
<td>3.5 (±0.1) 3.2 (±0.1) 3.0 (±0.1)</td>
<td>14.6 (±0.2) 12.8 (±0.3) 10.0 (±0.3)</td>
<td>3053 (±5) 1592 (±88) 1217 (±103)</td>
</tr>
<tr>
<td>18</td>
<td>0.58 (±0.02) 0.87 (±0.01)</td>
<td>48.7 (±1.0) 49.9 (±0.2)</td>
<td>3.3 (±0.1) 3.2 (±0.1)</td>
<td>13.7 (±0.2) 10.8 (±0.2)</td>
<td>1675 (±112) 1341 (±93)</td>
</tr>
<tr>
<td>21</td>
<td>0.51 (±0.01) 0.82 (±0.01)</td>
<td>46.0 (±1.0) 49.5 (±0.2)</td>
<td>3.4 (±0.1) 3.3 (±0.1)</td>
<td>14.0 (±0.2) 11.0 (±0.2)</td>
<td>2198 (±156) 1598 (±103)</td>
</tr>
<tr>
<td>25</td>
<td>0.32 (±0.01) 0.73 (±0.04)</td>
<td>45.9 (±1.0) 49.2 (±0.2)</td>
<td>3.5 (±0.1) 3.4 (±0.1)</td>
<td>14.5 (±0.3) 11.7 (±0.3)</td>
<td>2958 (±24) 1592 (±6)</td>
</tr>
</tbody>
</table>

1 Data based on average of 6 estimations. Figures in parenthesis are % values giving an indication of the standard error of the mean.
<table>
<thead>
<tr>
<th>NO. DAYS STORED</th>
<th>ACIDITY expressed as (% citric acid)</th>
<th>VITAMIN C (mg/100 g pulp)</th>
<th>SUGAR (%)</th>
<th>TOTAL CAROTENOIDS expressed as (μg β-carotene/100g pulp)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CONTROL 0.75% PROC. 1.0% PROC.</td>
<td>CONTROL 0.75% PROC. 1.0% PROC.</td>
<td>CONTROL 0.75% PROC. 1.0% PROC.</td>
<td>CONTROL 0.75% PROC. 1.0% PROC.</td>
</tr>
<tr>
<td>0</td>
<td>1.60 (±0.01) 1.60 (±0.01) 1.60 (±0.01)</td>
<td>58.3 (±0.8) 58.3 (±0.8) 58.3 (±0.8)</td>
<td>2.7 (±0.1) 2.7 (±0.1) 2.7 (±0.1)</td>
<td>7.2 (±0.2) 7.2 (±0.2) 7.2 (±0.2)</td>
</tr>
<tr>
<td>2</td>
<td>1.24 (±0.01) 1.27 (±0.01) 1.34 (±0.01)</td>
<td>54.3 (±0.5) 56.1 (±0.7) 56.7 (±0.6)</td>
<td>2.9 (±0.2) 2.8 (±0.3) 2.7 (±0.2)</td>
<td>11.2 (±0.3) 9.5 (±0.2) 7.4 (±0.2)</td>
</tr>
<tr>
<td>5</td>
<td>0.58 (±0.01) 0.77 (±0.01) 1.28 (±0.01)</td>
<td>37.6 (±0.7) 48.9 (±0.9) 52.3 (±1.5)</td>
<td>3.1 (±0.3) 3.0 (±0.2) 2.9 (±0.2)</td>
<td>13.6 (±0.2) 10.7 (±0.3) 7.9 (±0.3)</td>
</tr>
<tr>
<td>7</td>
<td>0.22 (±0.01) 0.63 (±0.01) 0.90 (±0.01)</td>
<td>33.0 (±1.0) 41.5 (±0.9) 48.3 (±0.8)</td>
<td>3.9 (±0.2) 3.3 (±0.2) 3.1 (±0.2)</td>
<td>15.5 (±0.2) 11.6 (±0.2) 8.6 (±0.2)</td>
</tr>
<tr>
<td>4</td>
<td>0.56 (±0.02) 0.76 (±0.01)</td>
<td>38.4 (±1.3) 44.2 (±1.4)</td>
<td>3.4 (±0.1) 3.3 (±0.2)</td>
<td>12.8 (±0.2) 9.2 (±0.2)</td>
</tr>
<tr>
<td>11</td>
<td>0.41 (±0.01) 0.61 (±0.01)</td>
<td>36.1 (±1.0) 42.7 (±0.9)</td>
<td>3.8 (±0.2) 3.4 (±0.2)</td>
<td>13.5 (±0.3) 10.3 (±0.2)</td>
</tr>
<tr>
<td>13</td>
<td>0.23 (±0.01) 0.56 (±0.01)</td>
<td>34.6 (±0.7) 39.6 (±1.0)</td>
<td>3.9 (±0.1) 3.6 (±0.1)</td>
<td>14.8 (±0.2) 11.2 (±0.2)</td>
</tr>
</tbody>
</table>

1 Data based on 6 replicates.

Figures in parenthesis are ±W values giving an indication of the standard error of the mean.
### TABLE 13
CHANGES IN CHEMICAL CONSTITUENTS IN MANGO VAR. HADEN DURING STORAGE AT 25 ± 2°C/85-95% R.H.¹

<table>
<thead>
<tr>
<th>N. DAYS STORED</th>
<th>ACIDITY (%)</th>
<th>VITAMIN C (mg/100 g pulp)</th>
<th>SUGAR (%)</th>
<th>TOTAL CAROTENOID (µg ß-carotene/100g pulp)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CONTROL 0.75% PRO-LONG</td>
<td>1.0% PRO-LONG</td>
<td>CONTROL 0.75% PRO-LONG</td>
<td>1.0% PRO-LONG</td>
</tr>
<tr>
<td>0</td>
<td>1.70</td>
<td>1.70</td>
<td>1.70</td>
<td>22.0</td>
</tr>
<tr>
<td>3</td>
<td>0.78</td>
<td>1.55</td>
<td>1.60</td>
<td>17.4</td>
</tr>
<tr>
<td>5</td>
<td>0.43</td>
<td>0.87</td>
<td>1.48</td>
<td>14.4</td>
</tr>
<tr>
<td>7</td>
<td>0.13</td>
<td>0.64</td>
<td>1.30</td>
<td>14.0</td>
</tr>
<tr>
<td>10</td>
<td>0.50</td>
<td>1.00</td>
<td>1.76</td>
<td>18.2</td>
</tr>
<tr>
<td>13</td>
<td>0.12</td>
<td>0.37</td>
<td>1.63</td>
<td>17.0</td>
</tr>
</tbody>
</table>

¹ Data based on average of 2 estimations.
FIG. 13  CHANGE IN TOTAL SOLUBLE SOLIDS CONTENT AND ACIDITY IN MANGO VAR. JULIE STORED AT

\[13(±2)°C/85-95\% \text{ R.H.}\]

- Control
- \(1\%\) Pro-long
- \(135\%\) Pro-long

TSS: ———
Acidity: ———

<table>
<thead>
<tr>
<th>NO. DAYS STORED</th>
<th>TSS (°BRIX)</th>
<th>ACIDITY (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>10</td>
<td>17</td>
<td>9</td>
</tr>
<tr>
<td>14</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td>18</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>22</td>
<td>15</td>
<td>3</td>
</tr>
</tbody>
</table>
FIG. 14 CHANGES IN TOTAL SOLUBLE SOLIDS CONTENT AND ACIDITY IN MANGO VAR. JULIE STORED AT 25(±2)/85-95% R.H.

-75-

NO. DAYS STORED

TOTAL SOLUBLE SOLIDS (°BRIX)

ACIDITY (%)

13 15 17 19

2 4 6 8 10 12

Control
O 0.75% Pro-long

△ 1% Pro-long

--- TSS---

--- Acidity

-75-
increase in the total soluble solids content is accompanied by a decrease in acidity. This inverse relationship was true for all treatments under both storage conditions. The reduction in acidity during ripening plays an important role in the acid:sugar balance and consequently in influencing the taste and flavour of the fruit (see section 2.4.2).
4.7 VITAMIN C

There was a steady fall in the vitamin C content in both control and Pro-long treated fruits but the loss was greater in the control mangoes during the entire storage period (see Tables 11, 12 and 13).

For mango var. Julie, there was a greater loss in vitamin C content in fruits stored at 25°C than those stored at 13°C (see Tables 11 and 12).

The var. Haden had a lower vitamin C content than the var. Julie (see Table 13).

As suggested in section 2.4.4, mango is a good source of vitamin C and therefore from a nutritional point of view, the use of Pro-long seemed to be of some advantage in that there was an increased retention in vitamin C content in Pro-long treated fruits at the end of the storage period despite the extension in shelf-life.
4.8 SUGAR

DESCENDING PAPER CHROMATOGRAPHY

The use of paper chromatography confirmed the presence of glucose, fructose and sucrose in the pulp of ripe mangoes (see Plate 2 and Table 14). A small amount of an unknown sugar was also detected having an \( R_g \) value of 41 (appearing between the maltose and sucrose spot on the chromatogram). Paper chromatography characteristics of the unknown sugar suggest that it could be an aldose.

QUANTITATIVE ANALYSIS

Sugar content like acid content is an important criterion used in determining the ripening and storage behaviour in mango. Both reducing and total sugar content were determined at regular intervals during storage. Regardless of the variety or storage conditions, there was only a slight increase in the reducing sugar content whereas the total sugar content increased markedly throughout ripening (see Tables 11, 12 and 13). For var. Julie, slightly higher values for both reducing and total sugar content were recorded in mangoes stored at 25°C when compared to those stored at 13°C.

The control mangoes recorded the highest values for both reducing and total sugar content under both conditions of storage. A similar observation was made while recording the total soluble solids content (see section 4.4).

For mango var. Julie stored at 13°C, the control mangoes had a total sugar content of 14.6% at the end of the storage period while the 1.0% Pro-long treated fruits had a total sugar content of 14.5%. The 1.25% Pro-long treated fruits had a total sugar
PLATE 2  PAPER CHROMATOGRAM WITH SILVER NITRATE-SODIUM ETHOXIDE DETECTION FOR QUALITATIVE ANALYSIS OF SUGARS IN RIPE MANGO PULP

F, Fructose; G, Glucose; M, Maltose; S, Sucrose; U, Unknown.
### Table 14
**Paper Chromatography Characteristics of Marker Compounds and Sample**

<table>
<thead>
<tr>
<th>R&lt;sub&gt;g&lt;/sub&gt; Values in Ethyl Acetate-Acetic Acid-Water, 14:3:3</th>
<th>Colour Reactions with Detection Reagents</th>
</tr>
</thead>
<tbody>
<tr>
<td>SILVER NITRATE-SODIUM ETHOXIDE</td>
<td>P-ANISIDINE-HCl at 60°C</td>
</tr>
<tr>
<td>GLUCOSE&lt;sup&gt;1&lt;/sup&gt;</td>
<td>100</td>
</tr>
<tr>
<td>FRUCTOSE&lt;sup&gt;1&lt;/sup&gt;</td>
<td>136</td>
</tr>
<tr>
<td>SUCROSE&lt;sup&gt;1&lt;/sup&gt;</td>
<td>53</td>
</tr>
<tr>
<td>MALTOSE</td>
<td>34</td>
</tr>
<tr>
<td>UNKNOWN&lt;sup&gt;1&lt;/sup&gt;</td>
<td>41</td>
</tr>
</tbody>
</table>

<sup>1</sup> Sugars detected in mango pulp.
content of 11.7% at the end of the storage period i.e. 2.9% lower than the total sugar content of control mangoes (see Table 11).

For mango var. Julie stored at 25°C, the control mangoes had a total sugar content of 15.5% while the 0.75% Pro-long treated fruits had a total sugar content of 14.8%. The 1.0% Pro-long treated fruits had a total sugar content of 11.2% at the end of the storage period i.e. 4.3% lower than the total sugar content of control mangoes (see Table 12). A similar trend was noticed in mango var. Haden stored at 25°C (see Table 13).

Considering the two varieties, the var. Haden had a lower total sugar content compared to var. Julie stored at 25°C at the end of the storage period. This was also reflected in the total soluble solids content (see section 4.4).
4.9 TOTAL CAROTENOIDS

Results in Tables 11, 12 and 13 and graphs in Figs. 15 and 16 suggest that the increase in carotenoid content in control mangoes was more rapid when compared to the Pro-long treated fruits. In mango var. Julie, higher values were recorded for fruits stored at 25°C than those stored at 13°C. The results seem to suggest that carotenoid formation was inhibited in mangoes stored under optimum low-temperature conditions.

The use of 1.25% Pro-long at 13°C and 1.0% Pro-long at 25°C had a marked inhibitory effect on carotenoid formation. On the other hand, the use of lower concentrations of Pro-long i.e. 1.0% Pro-long at 13°C and 0.75% Pro-long at 25°C had a very slight inhibitory effect on carotenogenesis. This was also reflected in the taste panel work (see section 4.11).

Srivastava et al. (1962) suggested that the use of low temperature storage and/or skin coatings affected carotenogenesis (see section 2.4.3).
FIG. 15  CHANGES IN CAROTENOID CONTENT IN MANGO VAR. JULIE STORED AT 13(+2)°C/85-95% R.H.
FIG. 16 CHANGES IN CAROTENOID CONTENT IN MANGO VAR. JULIE DURING STORAGE AT 25(±2)°C/85-95% R.H.
4.10 ETHANOL CONTENT

Ethanol content was determined in mangoes at the end of the storage period. Fig. 17 gives typical G.L.C. traces for ethanol content in mango var. Julie stored at 25°C. Propanol was used as an internal standard. The results in Table 15 were obtained for ethanol content in ripe mangoes of different varieties stored at 13°C and 25°C, having received various Pro-long treatments. The ethanol content in the mango pulp was measured at the end of the storage period for each treatment.

No ethanol was detected in control mango var. Julie stored at 13°C (see Table 15). Results seem to suggest that Pro-long concentrations greater than 1% set up anaerobic conditions in the mango fruits stored at 13°C causing fermentative decarboxylation resulting in significant levels of ethanol accumulating in the mango pulp. For mangoes stored at 25°C, Pro-long concentrations greater than 0.75% caused anaerobiosis in the fruit. Thus the use of higher Pro-long concentrations i.e. 1.25% at 13°C and 1.0% at 25°C adversely affected the organoleptic qualities of the fruit as corroborated by taste panel studies (see section 4.11).
FIG. 17 CHROMATOGRAMS SHOWING ETHANOL CONTENT IN MANGO VAR. JULIE STORED AT 25(+2)°C/85-95% R.H. USING PROPA NOL AS AN INTERNAL STANDARD

CONTROL | 0.75% PRO-LONG | 1.0% PRO-LONG

pk ht E = 0.04 | 0.05 | 0.14 | 0.17 | 1.72 | 1.63
pk ht P = 0.02 | 0.02 | 0.07 | 0.08 | 0.82 | 0.79

% ethanol = 0.02 | 0.02 | 0.07 | 0.08 | 0.82 | 0.79

(pk ht E = peak height of ethanol; pk ht P = peak height of propanol)
## TABLE 15: ESTIMATION OF ETHANOL CONTENT IN MANGO PULP BY G.L.C. USING PROPA O L AS AN INTERNAL STANDARD

<table>
<thead>
<tr>
<th>VARIETY</th>
<th>STORAGE CONDITION</th>
<th>TREATMENT</th>
<th>RATIO ( \frac{\text{PEAK HEIGHT OF ETHANOL}^2}{\text{PEAK HEIGHT OF PROPA O L}} )</th>
<th>% ETHANOL CONTENT(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JULIE</td>
<td>OPTIMUM LOW TEMP. (13(\pm)2(^\circ)C/85-95% R.H.)</td>
<td>CONTROL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>CONTROL</td>
<td>0.076 (+0.008)</td>
<td>0.04 (+0.004)</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>1.0% PRO-LONG</td>
<td>1.125 (+0.06)</td>
<td>0.53 (+0.03)</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>1.25% PRO-LONG</td>
<td>0.076 (+0.008)</td>
<td>0.04 (+0.004)</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>1.0% PRO-LONG</td>
<td>1.125 (+0.06)</td>
<td>0.53 (+0.03)</td>
</tr>
<tr>
<td>JULIE</td>
<td>TROPICAL AMBIENT (25(\pm)2(^\circ)C/85-95% R.H.)</td>
<td>CONTROL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>CONTROL</td>
<td>0.076 (+0.008)</td>
<td>0.04 (+0.004)</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>0.75% PRO-LONG</td>
<td>0.153 (+0.007)</td>
<td>0.075 (+0.002)</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>1.0% PRO-LONG</td>
<td>0.153 (+0.007)</td>
<td>0.075 (+0.002)</td>
</tr>
<tr>
<td>HADEN</td>
<td>TROPICAL AMBIENT</td>
<td>CONTROL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>CONTROL</td>
<td>0.076 (+0.008)</td>
<td>0.04 (+0.004)</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>0.75% PRO-LONG</td>
<td>0.153 (+0.007)</td>
<td>0.075 (+0.002)</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>1.0% PRO-LONG</td>
<td>0.153 (+0.007)</td>
<td>0.075 (+0.002)</td>
</tr>
<tr>
<td>NGOWE</td>
<td>TROPICAL AMBIENT</td>
<td>CONTROL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>CONTROL</td>
<td>0.076 (+0.008)</td>
<td>0.04 (+0.004)</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>1.0% PRO-LONG</td>
<td>0.153 (+0.007)</td>
<td>0.075 (+0.002)</td>
</tr>
</tbody>
</table>

1 Ethanol content estimated after last day of storage.

2 Data based on 4 separate estimations (all injections were carried out in duplicate).

Figures in parenthesis are \(\sigma/\bar{x}\) values giving an indication of the standard error of the mean.
4.11 TASTE PANEL WORK

Taste panel work was carried out on mango var. Julie at the full-ripe stage (last day stored) to assess the following attributes: colour, texture, mango aroma, taste and "off-flavour". The scores awarded by the panellists were statistically treated using the student's t-test. The significance of the t-values obtained was assessed using the percentage points of the t-distribution (with 9 degrees of freedom in each case) at the 5% to 0.1% levels (Murdoch and Barnes, 1974).

4.11.1 COLOUR

Colour is an important parameter influencing consumer appeal. The bright orange-yellow colour of the mango pulp is often displayed in order to attract the consumer. Results in Table 16a indicate that for mangoes stored at 13°C, the control fruits had the highest rating (mean score = 4.2) i.e. the most intense colour, followed by the 1.0% Pro-long treated fruits (mean score = 3.8). The 1.25% Pro-long treated fruits had the lowest rating (mean score = 1.7).

Using the t-test (see Table 16b), the difference between the control fruits and the 1.0% Pro-long treated fruits was found to be not significant (t = 1.8) whereas the difference between the control fruits and the 1.25% Pro-long treated fruits was found to be highly significant (t = 11.2). The difference between the 1.0% Pro-long treated fruits and the 1.25% Pro-long treated fruits was also found to be highly significant (t = 11.7).

For mangoes stored at 25°C (see Table 17a), the panellists awarded the highest score for colour to the control fruits (mean score = 4.6), followed by the 0.75% Pro-long treated fruits (mean score = 4.3) while the 1.0% Pro-long treated fruits had the lowest rating (mean score = 2.4). The t-test results in Table 17b indicate that the difference between the control and the 0.75% Pro-long
### TABLE 16a TASTE PANEL ANALYSIS ON VAR. JULIE STORED AT 13°C

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>MEAN SCORES FOR PARAMETERS ASSESSED</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COLOUR</td>
<td>TEXTURE</td>
</tr>
<tr>
<td>CONTROL</td>
<td>4.2(0.42)</td>
<td>1.8(0.42)</td>
</tr>
<tr>
<td>1.0% PRO-LONG</td>
<td>3.8(0.42)</td>
<td>2.3(0.48)</td>
</tr>
<tr>
<td>1.25% PRO-LONG</td>
<td>1.7(0.48)</td>
<td>2.8(0.42)</td>
</tr>
</tbody>
</table>

1 Data based on 10 evaluations.
2 The score 1 indicates no "off-flavour" (see taste panel score sheet p. 52).

Figures given in parenthesis are standard deviations.

### TABLE 16b SIGNIFICANCE OF TASTE PANEL RESULTS USING PAIRED STUDENT’S t-TEST

<table>
<thead>
<tr>
<th>TREATMENTS PAIRED</th>
<th>PARAMETERS</th>
<th>COLOUR</th>
<th>TEXTURE</th>
<th>MANGO AROMA</th>
<th>TASTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL vs 1.0% PRO-LONG</td>
<td></td>
<td>**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONTROL vs 1.25% PRO-LONG</td>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>1.0% vs 1.25% PRO-LONG</td>
<td></td>
<td>***</td>
<td>*</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

Levels of Significance

- not significantly different 5%
- probably significantly different 5% - 1%
- significantly different 1% - 0.1%
- highly significantly different 0.1%
TABLE 17a  TASTE PANEL ANALYSIS ON VAR. JULIE STORED AT 25°C

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>COLOUR</th>
<th>TEXTURE</th>
<th>MANGO AROMA</th>
<th>TASTE</th>
<th>OFF-FLAVOUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL</td>
<td>4.6(0.51)</td>
<td>1.6(0.51)</td>
<td>3.7(0.46)</td>
<td>4.7(0.48)</td>
<td>1²</td>
</tr>
<tr>
<td>0.75% PRO-LONG</td>
<td>4.3(0.51)</td>
<td>1.7(0.48)</td>
<td>3.7(0.46)</td>
<td>4.3(0.48)</td>
<td>1²</td>
</tr>
<tr>
<td>1.0% PRO-LONG</td>
<td>2.4(0.51)</td>
<td>2.7(0.42)</td>
<td>1.7(0.48)</td>
<td>1.7(0.48)</td>
<td>3.3(0.78)</td>
</tr>
</tbody>
</table>

1 Data based on 10 evaluations.
2 The score 1 indicates "no off-flavour" (see taste panel score sheet p. 52).

Figures given in parenthesis are standard deviations.

TABLE 17b  SIGNIFICANCE OF TASTE PANEL RESULTS USING PAIRED STUDENT'S t-TEST

<table>
<thead>
<tr>
<th>TREATMENTS PAIRED</th>
<th>PARAMETERS</th>
<th>COLOUR</th>
<th>TEXTURE</th>
<th>MANGO AROMA</th>
<th>TASTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL vs 0.75% PRO-LONG</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CONTROL vs 1.0% PRO-LONG</td>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>0.75% vs 1.0% PRO-LONG</td>
<td></td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>

Levels of Significance

- not significantly different  
*** highly significantly different  

5%  0.1%
treated fruits was not significant (t = 1.4) whereas the difference between the control mangoes and the 1.0% Pro-long treated mangoes was highly significant (t = 8.82) and the difference between the 0.75% and the 1.0% Pro-long treated fruits was also found to be highly significant (t = 8.1).

Carotenoids are the major pigments imparting the orange-yellow colour to the mango pulp (see section 2.4.3). Since carotenogenesis was inhibited in the 1.25% Pro-long treated fruits stored at 13°C and the 1.0% Pro-long treated fruits stored at 25°C (see section 4.9), this would explain the lower ratings for colour for these two treatments.

4.11.2 TEXTURE

In the opinion of the panellists, for mangoes stored at 13°C (see Table 16a), the 1.25% Pro-long treated fruits had the firmest texture (mean score = 2.8) followed by the 1.0% Pro-long treated fruits and the controls (mean scores = 2.3 and 1.8 respectively). The difference between the control and the 1.0% Pro-long treated fruits was found to be significant (t = 3) while the difference between the control and 1.25% Pro-long treated fruits was found to be highly significant (t = 4.74). The difference in texture between the 1.0% and the 1.25% Pro-long treated fruits was found to be probably significant (t = 2.23) as shown in Table 16b.

Texture measurement using the Instron also indicated a similar trend with the 1.25% Pro-long treated fruits having the firmest texture (see section 4.5).

Results in Table 17a show that for mangoes stored at 25°C, the 1.0% Pro-long treated fruits had the firmest texture (mean score = 2.8), followed by the 0.75% Pro-long treated fruits (mean score = 1.7) and the controls (mean score = 1.6). The difference between the control and the 0.75% Pro-long treated fruits was found to be not
significant ($t = 0.76$), while the difference between the control and the 1.0\% Pro-long treated fruits was found to be highly significant ($t = 6$). Also the difference between the 0.75\% Pro-long treated fruits and the 1.0\% Pro-long treated fruits was found to be highly significant ($t = 4.7$) as shown in Table 17b. Texture measurements using the Instron also showed similar trends with the 1.0\% Pro-long treated fruits having the firmest texture (see section 4.5).

4.11.3  MANGO AROMA

The panellists were well familiar with the typical mango aroma associated with a normally ripened mango fruit and using this as an index carried out assessment on the samples provided.

Results in Table 16a indicate that for mangoes stored at 13\degree C, the 1.25\% Pro-long treated fruits had the lowest level of aroma (mean score = 1.7) while more mango aroma was detected in the control fruits and the 1.0\% Pro-long treated fruits (mean score = 3.9 and 3.6 respectively). The difference between the control and 1.0\% Pro-long treated fruits was found to be not significant ($t = 0.43$) while the difference between the control and the 1.25\% Pro-long treated fruits was found to be highly significant ($t = 13.5$). The difference between the 1.0\% and the 1.25\% Pro-long treated fruits was also found to be highly significant ($t = 7.76$) as shown in Table 16b.

Results in Table 17a indicate that for mangoes stored at 25\degree C, the control and the 0.75\% Pro-long treated fruits had the highest level of mango aroma (mean score = 3.7) while the 1.0\% Pro-long treated fruits had very little mango aroma (mean score = 1.7). There was no difference in mango aroma between the controls and the 0.75\% Pro-long treated fruits ($t = 0$) while the difference between the control and the 1.0\% Pro-long treated fruits was found to be highly significant ($t = 7.74$). Also the difference between the
0.75% and the 1.0% Pro-long treated fruits was found to be highly significant (t = 13.4) as shown in Table 17b.

Mango aroma was not assessed by any physical or chemical method since no straightforward method is available.

4.11.4 TASTE

The taste of mango was assessed on the degree of sourness or sweetness of the fruit using a five point scoring system whereby the score 1 indicated a bias towards sourness while the score 5 indicated a bias towards sweetness. Results in Table 16a show that for mangoes stored at 13°C, the 1.25% Pro-long treated fruits were sour to taste (mean score = 1.7) while the control and the 1.0% Pro-long treated fruits were sweet to taste (mean score = 3.9 and 3.6 respectively). The difference between the control and the 1.0% Pro-long treated fruits was not significant (t = 1.2), but the difference in taste between the control and the 1.25% Pro-long treated fruits and; the difference between the 1.0% and the 1.25% Pro-long treated fruits was found to be highly significant (t = 9.5 and 8.14 respectively).

Results in Table 17a show that for fruits stored at 25°C, the 1.0% Pro-long treated fruits were adjudged to be sour (mean score = 1.7) while the control and the 0.75% Pro-long treated fruits were sweet to taste (mean scores = 4.7 and 4.3 respectively). The difference between the control and the 0.75% Pro-long treated fruits was not significant (t = 1.8), while the difference between the control and the 1.0% Pro-long treated fruits; and the difference between the 0.75% and the 1.0% Pro-long treated fruits was found to be highly significant (t = 11.6 and 11.8 respectively).

The sour taste of the 1.25% Pro-long treated fruits stored at 13°C and the 1.0% Pro-long treated fruits stored at 25°C can be attributed to the higher acid content and the lower sugar content
in these fruits (see sections 4.6 and 4.8).

4.11.5 **OFF-FLAVOUR**

Results in Table 16a and 17a show that off-flavour was only detected in the 1.25% Pro-long treated fruits stored at 13°C and the 1.0% Pro-long treated fruits stored at 25°C (mean scores = 2.3 and 3.8 respectively). No off-flavour was detected in all the other samples assessed by the panellists (mean score = 1). The t-test was therefore not carried out on this data.

Results in section 4.10 indicated that 1.25% Pro-long treatment of mangoes at 13°C and 1.0% Pro-long treatment of mangoes at 25°C resulted in accumulation of significant amounts of ethanol in the mango pulp. This was due to anaerobiosis causing metabolic disorders in the fruit. The presence of off-flavour in these fruits is clearly due to the abnormal ripening of the fruits.

4.11.6 **OVERALL ACCEPTABILITY**

Under the column headed "any other comments" (see Fig. 6), the panellists were requested to record the overall acceptability of the samples along with any other observations. All panellists found the 1.25% Pro-long treated fruits stored at 13°C and the 1.0% Pro-long treated fruits stored at 25°C to be unacceptable. All the other samples were acceptable.

A series of photographs on mango var. Julie stored at 25°C are given in the appendix. Some of the typical changes in the external and internal features of the variety which affect consumer appeal are depicted.
5. CONCLUSIONS

Two difficulties were encountered during this study with respect to the mangoes supplied. Firstly, the history of the fruits supplied was not fully known, however the supplier indicated that the fruits were not more than seven days post-harvest and were in all cases pre-climacteric. Secondly, several batches suffered from anthracnose and these batches were discarded after mycological studies had been carried out. However in the rest of the batches, benomyl was found to be an effective fungicide in the control of incipient surface infections (see section 4.1). Mango var. Julie was used in storage trials at both 13°C and 25°C, while the variety Haden was also used in storage trials at 25°C.

Despite the above constraints, from the data obtained on the mango varieties tested in this study, the following conclusions can be drawn in relation to the aims of the present work as set out in section 2.7.

A. The optimum Pro-long concentration for use when storing mangoes at 13°C was found to be 1% while 0.75% Pro-long produced the best results for mangoes stored at 25°C.

B. Loss in physiological weight was retarded in Pro-long treated fruits and there was increased retention in the vitamin C content. Data obtained from the physico-chemical analysis on the varieties tested indicate that fruits treated with the optimum Pro-long concentrations, i.e. 1% Pro-long at 13°C and 0.75% Pro-long at 25°C.
produced fruits with normal physico-chemical characteristics at the end of the storage period when compared to the full-ripe controls and they were found to be organoleptically acceptable. The use of higher Pro-long concentrations, i.e. 1.25% at 13°C and 1.0% at 25°C caused anaerobiosis in the mango fruit resulting in the accumulation of ethanol in the mango pulp thus adversely affecting the organoleptic quality of the fruit.

C. The retardation of the ripening process in Pro-long treated fruits facilitated extension in storage life at both 13°C and 25°C. Almost a doubling in shelf-life was achieved under both storage conditions.

Since control mangoes stored at 13°C had a shelf-life of 13 days and Pro-long treated fruits stored at 25°C also had a shelf-life of 13 days, there is every possibility of either reducing and/or replacing completely the use of low temperature during transhipment and storage, thus leading to a reduction in cost.
6. **SUGGESTIONS FOR FURTHER WORK**

a) Storage trials should be carried out immediately post-harvest in order to assess the effect of Pro-long used at this early stage.

b) Having established the advantage of Pro-long in retarding moisture loss, further investigations should be carried out in order to study the effect of Pro-long under conditions of lower humidity, since storage warehouses often have humidities below 85%.

c) It is also necessary to establish whether the optimum Pro-long concentrations obtained in this study would be applicable under actual commercial storage conditions, bearing in mind that the storage cabinets used in this study had very efficient air circulation systems and very small quantities of fruits were stored.

d) Although Julie and Haden were the two main mango varieties studied in detail with respect to the physico-chemical changes during storage, it would be interesting to extend the use of Pro-long to other varieties. It would be particularly interesting to study the exact physiological behaviour of the fruit surface of the different varieties both with and without the Pro-long coating. The differences between varieties in terms of thickness of the peel, stomatal distribution, number of stomata per unit area etc., might necessitate the use of different Pro-long concentrations.
e) In-depth studies on the respiratory pattern of the mango fruit, both with and without Pro-long treatment under different conditions of storage should be carried out. Such studies could lead to the setting up of mathematical models that would aid in predicting the optimum Pro-long concentrations for use on the mango and other fruits under different conditions of storage.
Control and 0.75% Pro-long treated fruits, at the beginning of the storage period, showing olive-green ground colour. The Pro-long treated fruit shows a slight gloss.

Control mango showing a yellowish blush on ripening. 0.75% Pro-long treated mango still retaining its olive-green ground colour.
Senescent control mango showing extensive shrivelling and softening. 0.75% Pro-long treated mango showing a slight yellowish blush.

Soft/mushy pulp of senescent control mango.
Full-ripe control mango after 7 days storage.

Full-ripe 0.75% Pro-long treated mango after 14 days storage.
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