EFFECT OF LOWERING THE TEMPERATURE OF THE COLD STORAGE REGIME ON THE QUALITY OF EXPORT MANGOES AFTER FOUR WEEKS OF STORAGE

ABSTRACT

The effect on post-storage fruit quality of storing fruit of a number of mango cultivars for four weeks at temperatures of and lower than 11°C, viz., 8°C and 6°C, incorporating step-wise reductions in temperature was investigated. The greatest quantity of good quality and marketable Irwin and Kent fruit was obtained when the fruit were stored at the regime of two weeks at 8°C followed by two weeks at 6°C (8/8/6/6). In Zill, quantity of good quality and marketable fruit was greatest when fruit were stored at the regime, 11/11/8/8. Tommy Atkins and Sensation fruit performed equally well at every storage regime tested. Keitt fruit were highly susceptible to chilling injury, yielding the highest quantity of marketable and good quality fruit when stored at the warmest regime, 11/11/11/11. Differences in performance were apparently due to an interplay of factors, viz., predisposition to post-harvest decay, temperature tolerances of pathogens for growth, degree of softening in cold storage, and susceptibility to chilling injury.

INTRODUCTION

The mango (Mangifera indica L.) was reported to be one of the five major fruit crops in the world (Amm, 1990). Increasing popularity was been partly attributed to increasing demand in western European countries (Prinsley, 1987). Prices currently obtained for South African fruit on European markets are very favourable. For shipped fruit, however, high levels of wastage due to post-harvest decay have been experienced.

Medlicott and Jeger (1987) concluded, in considering world export in general, that sea transport appears essential for increasing trade volumes and reducing costs on foreign markets. As opposed to air freight, shipping holds an extra dimension to exporting mangoes since fruit stored for extended periods of time are far more prone to post-harvest decay. Post-harvest diseases, arising due to pre-harvest pathogen infection, present a high risk since they often only manifest themselves once the fruit begins to soften after packing.

Colletotrichum gloeosporioides Penz, incitant of anthracnose, and Hendersonia cereberrina Syd. and Butl., incitant of soft-brown rot, have been reported to be the major causal organisms of mango, post-harvest decay in South Africa (Dodige, 1924; Brodrick and Van der Westhuizen, 1976; Wehner, Bester, Kotze and Brodrick, 1981; Wehner, Bester and Kotze, 1982). Refrigerated storage is employed worldwide to extend the shelf-life of mangoes. Detailed studies indicating optimum storage temperature regimes are lacking, however. Currently, the time taken for South African mangoes to reach European markets from the time of packing is four weeks, with fruit generally being shipped at 11°C.

Studies to date have largely been concerned with effects of storage temperatures in causing chilling injury and yielding acceptable fruit in terms of appearance and taste. They have been little concerned with effects of temperature in minimising losses due to post-harvest decay which, for South African fruit exported this season, far outweighed losses due to any other cause.

It is well recognised that low temperatures retard fungal growth and colonisation as well as slow or retard ripening. Temperatures below 12°C are, however, considered to hold a danger to mango fruit in causing chilling injury (Medlicott and Jeger, 1987). Much has come to the fore indicating that cold conditioned fruit, i.e. fruit stored first at relatively high storage temperatures, is less susceptible to chilling injury, and can thus be stored at temperatures that would otherwise cause chilling injury (Akamine, 1963; Mukerjee and Srivastava, 1979; Thomas and Joshi, 1988).

The present study was performed to investigate the effect on fruit quality and post-harvest decay of storing fruit of the cultivars, Irwin, Zill, Sensation, Tommy Atkins, Kent and Keitt, for four weeks at temperatures of and lower than 11°C, viz., 8°C and 6°C, incorporating step-wise reductions in temperature.

MATERIALS AND METHODS

Newly packed fruit of the aforementioned cultivars were obtained from commercial packhouses during the months of January through March 1990, and stored at the following storage temperature regimes (abbreviations for the regimes are presented in parentheses):

2. Three weeks at 11°C followed by one week at 8°C (11/11/8/8).
3. Two weeks at 11°C followed by two weeks at 8°C (11/11/8/8).
4. One week at 11°C followed by two weeks at 8°C followed by one week at 6°C (11/8/8/6).
5. Two weeks at 8°C followed by two weeks at 6°C (8/8/6/6).
6. One week at 8°C followed by three weeks at 6°C (8/6/6/6).
7. Four weeks at 6°C (6/6/6/6).

Prior to packing, the fruit were given a five minute, 50°C, hot-water dip and coated with fungicides and wax.

For each cultivar, cartons of fruit were taken from a pallet, the fruit of a pallet having come from a particular grower. Fruit counts per carton for a cultivar were necessarily constant. Treatments (regimes) were randomly allocated to cartons. Nine cartons of fruit of each cultivar, except for Tommy Atkins, were stored at each regime. Six cartons of Tommy Atkins fruit per re-
gime were used due to reduced availability. Seven randomly selected cartons of fruit of each cultivar were utilised to ascertain stage of maturity prior to cold storage. Degree of ripeness was assessed on pulp penetration pressure (Pp) using a penetrometer to which a 6 mm plunger was attached (piercing surface = 0.28 cm² = A). Fruit were first peeled with a potato peeler to a depth of 2 to 3 mm to expose the mesocarp. The average of three readings per fruit was recorded.

Three cold rooms were utilised, each set to a fixed temperature. Hence, where a storage regime incorporated more than one temperature, fruit were transferred from one cold room to another. The cold rooms were not equipped with humidifiers, and hence, humidity and temperature were positively related. Cold room temperature was monitored by sensors linked to a computer as well as hygro-thermographs placed in the cold rooms. The latter additionally recorded relative humidity. Temperature variation was generally within 1°C. Relative humidity in the 6°C cold room was in the region of 65%, and in the 8 and 11°C cold rooms, in the region of 90%.

Directly after cold storage, half the fruit per carton were evaluated. The remaining fruit were left to ripen in a laboratory where the temperature varied between 18 and 25°C. Once reaching the stage when firm-ripe, i.e. showing penetrometer readings of 0.5 to 1.5 kGA, these fruit were assessed.

Post-harvest rots, chilling injury and any physiological disorder/s present, were each subjectively rated on a discontinuous scale from 0 to 3, where fruit rated 0 were free of symptoms, fruit rated 1 exhibited mild symptoms, fruit rated 2 showed moderate symptoms, and fruit rated 3 were severely affected. Decay symptoms originating at the stem-end were classified as stem-end rot and symptoms originated away from the stem-end as soft-brown rot except, in either case, when symptoms were typical of anthracnose rot. External colour was visually assessed as a percentage on a discontinuous scale, where estimates were either 0, 25, 50, 75 or 100. Fruit were additionally noted for lenticel spotting, sunburn, skin shrivelling, latex burn and other noticeable skin blemishes.

Total soluble solids content of the pulp, determined with a refractometer and expressed in brix (%), was only recorded for the Kent and Keitt fruit; for the Kent fruit when it reached the stage when firm-ripe, and for the Keitt fruit directly after cold storage and when it reached the stage when firm-ripe. The average of two readings per fruit was recorded.

Degree of ripeness, rated on pulp penetration pressure, was assessed directly after cold storage. Pulp penetration pressures were recorded as described previously.

Fruit free of physiological disorders, unsightly skin blemish (noticeable shrivelling, chilling injury or latex burn) and visible signs of disease infection, as well as being less than 75% green externally, were considered to be of good quality. Fruit free of any signs of post-harvest decay, and free or marginally affected by a physiological disorder, were considered marketable.

For purposes of representing a cold regime on a quantitative scale, the difference between the storage temperature and 20°C ("room temperature") was determined for each day of storage, and the differences obtained summed. In this way a measure of cold received relative to room temperature was obtained. This measure was expressed as cold units accumulated in degree days.

Data were subjected to analysis of variance incorporating polynomial regression, where variation due to storage regime was subdivided for reductions due to successive polynomial terms. For each analysis, variation of the means was interpreted in terms of the polynomial of degree of the highest term for which the reduction was taken as significant (significance levels of the reductions are shown in the figures presented).

RESULTS AND DISCUSSION

General: The high incidence of decay upon fruit ripening revealed that the mango fruit used were, for the most part, highly predisposed to post-harvest decay after leaving the packhouse.

Table 1 shows degree of external colouration and degree of ripeness (Pp) of each cultivar at the time the fruit were placed into cold storage. The Sensation fruit were least mature. The Irwin fruit were most mature, the majority being close to eating ripeness. The remaining cultivars were of similar ripeness. Only in the case of the Sensation fruit sampled, was degree of internal colouration less than 10% (data not shown).

External colouration of the Irwin, Zill and Kent fruit was relatively poor, whereas the Sensation, Tommy Atkins and Keitt fruit showed good external colouration at the onset of cold storage. Sensation and Tommy Atkins skin colouration was the result of a localised red hue caused by exposure of areas of the fruit to direct sunlight whilst on the tree.

Irwin: Five days after cold storage when the fruit were firm-ripe, percentage marketable and good quality fruit per carton generally increased then decreased as the storage regime became colder (Fig. 1). The greatest quantity of marketable and good quality fruit was obtained when fruit were stored at the regime, 8/8/6/6. Here, 27% of the fruit per carton were of good quality, and 48% marketable. All fruit stored at the currently adopted regime for export, 11/11/11/1, were unmarketable.

Fig. 2 shows the variation due to storage regime of pulp penetration pressure and degree of external fruit colouration direct-ly after cold storage. As the storage regime became colder, pulp penetration pressure increased in a sigmoidal manner from 0.64 to 2.4 kGA, whereas percentage skin colouration decreased in the opposite manner from 57 to 29, with both pressure and skin colouration leveling off at the regime, 8/8/6/6.

Pulp penetration pressure and degree of

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Pulp Penetration Pressure (kGA)</th>
<th>SE</th>
<th>Skin Colouration (%) brix</th>
<th>SE</th>
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<tr>
<td>Irwin</td>
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<td>30</td>
<td>23</td>
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<td>1.4</td>
<td>17</td>
<td>16</td>
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<tr>
<td>Sensation</td>
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<td>1.2</td>
<td>64</td>
<td>22</td>
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<tr>
<td>Tommy Atkins</td>
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<td>1.8</td>
<td>64</td>
<td>23</td>
</tr>
<tr>
<td>Kent</td>
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<td>0.8</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>Keitt</td>
<td>9.0</td>
<td>1.1</td>
<td>70</td>
<td>24</td>
</tr>
</tbody>
</table>

*A = 0.28 cm²
skin colouration before the fruit were placed in cold storage were in the order of 2.3 kg/m and 30% respectively. This indicates that ripening processes causing fruit softening and skin colouration did not proceed, or were severely retarded, when fruit were stored at the regimes, 8/8/6/6 and colder.

Following exposure of the fruit to room temperature after cold storage, decay set in quickly, especially anthracnose decay (Fig. 3). Fruit stored at the regime, 8/8/6/6, showed least decay when firm-ripe. The regimes warmer than this regime yielded greater percentages of decayed fruit per carton, the percentage of decayed fruit positively correlating with the warmness of the storage regime. Here, final percentage of decayed fruit appeared to relate, positively, to percentage of decayed fruit directly after cold storage (Fig. 4), which in turn seemed to reflect degree of softening in cold storage.

Susceptibility to post-storage decay increased the colder the storage regime became than the regime, 8/8/6/6 (Fig. 3). Fruit stored at the regimes, 8/6/6/6 and 6/6/6/6, were most susceptible to anthracnose rot. For these regimes, susceptibility to soft-brown rot increased with increasing cold, whereas susceptibility to stem-end rot decreased.

Directly after cold storage, the percentage of fruit per carton showing anthracnose symptoms was very temperature dependent, decreasing from 73 for the regimes, 11/11/11/11 and 11/11/11/8, to less than three for the regimes, 11/8/8/6 and colder (Fig. 4). The percentage of fruit per carton showing symptoms of stem-end and soft-brown rot decreased from eight and 12 respectively for the regime 11/11/11/11, to less than 1.5 for the regime, 8/8/6/6 and 6/8/6/6.

Fig. 5 shows the variation due to storage regime of degree of skin colouration five days after cold storage. Average skin colouration of the fruit per carton decreased from 67 to 40% with increasing cold, this variation apparently relating to the variation in colour directly after cold storage.

Evidently, further colouration of the fruit stored at the regimes, 8/8/6/6 and colder,
where fruit colouration during cold storage was minimal, did occur after storage. The incidence of physiological disorders was exceedingly small, bearing no relation to storage regime (data not shown).

**Zill** The Zill fruit were highly prone to post-harvest decay. Seven days after cold storage when fruit unaffected by decay were firm-ripe, decay of affected fruit was advanced. The greatest quantity of marketable and good quality fruit was obtained when fruit were stored at the regime, 8/8/6/6 (Fig. 7). Here, 12% of the fruit per carton were both marketable and of good quality. Carton percentages of marketable and good quality fruit for the remaining storage regimes varied between three and seven.

The variation due to storage regime of pulp penetration pressure and degree of external fruit colouration directly after cold storage is shown in Fig. 8. As the storage regime became colder, pulp penetration pressure generally increased from 1 to 3 kg/A, whereas percentage skin colouration first decreased from 70 to a low of 22 (8/8/6/6) then increased to 31.

Pulp penetration pressure and percentage skin colouration before the fruit were placed in cold storage were in the order of 7,7 kg/A and 17 respectively. Hence, ripening processes causing fruit softening and skin colouration proceeded during cold storage at every regime. The rate at which these processes occurred was, however, much more rapid for fruit stored at the regime, 11/11/11/11, than for fruit stored at the remaining storage regimes where differences between regimes in pressure and colour directly after cold storage were relatively small.

Due to the advanced degree of rotting when fruit unaffected by decay were firm-ripe, it was difficult to assess which diseases were responsible for the decay noted at this time.

**Fig. 9** shows the variation due to storage regime in disease incidence directly after cold storage. The percentage of fruit per carton showing anthracnose symptoms decreased from 59 for the regime, 11/11/11/11, to less than five for the regimes, 8/8/6/6 and colder. The incidence of stem-end rot generally decreased from 73% for the regime, 11/11/11/11, to less than 12% for the regimes, 8/8/6/6 and colder. Differences in the incidence of soft-brown rot between storage regimes were far less pronounced. Here, as the cold regime became colder, the percentage of affected fruit per carton first decreased from 70 to a low of 28 (11/8/8/6), then increased to 48.

It would appear that fruit stored at the regime, 11/11/11/11, were equally susceptible to anthracnose, stem-end rot and soft-brown rot development. For the colder regimes, however, conditions were more favourable for the development of soft-brown rot. Indicated in a lower temperature threshold for the development of this rot in view of the fact that softening occurred in similar degrees during storage for the regimes colder than 11/11/11/11. Moreover, a slightly higher tolerance of stem-end rot to cold as opposed to anthracnose is indi-
Figure 5: Percentage of noticeably shriveled Irwin fruit directly after cold storage.

Figure 6: External colouration of Irwin fruit when the fruit reached the stage when firm-ripe.

cated by the differences in incidence of these rots for the regimes, 11/11/8/8 and colder. The pronounced increase in the incidence of soft-brown rot for the coldest regime, 8/6/6/6, in relation to the regimes just warmer than this regime, appeared to be indicative of the occurrence of chilling injury at the coldest regime and the elevated ability of soft-brown rot to colonise chill injured fruit in cold storage.

Fruit stored at the regime, 8/6/6/6, showed least decay when firm-ripe. The greater incidence of decay of the fruit stored at the remaining regimes can be reasoned in terms of the level of decay directly after cold storage, and chilling injury to fruit stored at the coldest regime (see Irwin). Directly after cold storage, the incidence of fruit showing noticeable shrivelling increased linearly with increasing cold from 2 to 7,6% of the fruit per carton (Fig. 10). Due to the severity of post-storage decay, assessment of external colouration of decayed fruit when fruit unaffected by decay were firm-ripe was not possible. The few healthy fruit remaining were, however, well coloured (85 ± 21%).

The incidence of physiological disorders was exceedingly small and found to bear no relation to storage regime (data not shown).

Sensation The Sensation fruit appeared to show resistance to pathogen infection in the field and/or pathogen development post-harvest. Storage regime had no apparent effect on percentage good quality and marketable fruit directly after cold storage, nor 14 days later when the fruit were firm-ripe. Directly after cold storage, 100% of the fruit per carton were of good quality. Fourteen days later, 65% (± 7,6%) per carton were of good quality and 89,9% (± 5,2%) per carton were marketable.

Quality degrading was more the result of the incidence of physiological disorders than that of post-storage decay or any other factor. The final levels of decay due to the various rots bore no relation to storage regime, ranging from 0 to 6% of the fruit per carton. Furthermore, the incidence of chilling injury (pitted necrotic spots) and noticeable shrivelling bore no relation to storage regime when the fruit were firm-ripe, the average levels of which were 1% and (± 0,8%) and 2% (± 1,5%) of the fruit per carton respectively.

A linear increase in the incidence of the physiological disorder, "jelly seed," was apparent with increasing cold (Fig. 11), the percentage of fruit per carton showing this disorder increasing from 4,6 to 13,5. In contrast, no relationship between the incidence of "soft nose," a similar physiological disorder to "jelly seed," and cold regime was apparent. On average, 7,3% (± 4,3%) of the fruit per carton showed visible signs of this disorder.

The incidence of tissue browning, characterised by narrow bands of corky brown tissue in the pulp, decreased inconsistently with increasing cold from 30,5 to 6,8% of the fruit per carton (Fig. 12). Browning and corking of the pulp are generally said to be effects of chilling injury, making this result difficult to explain.

Pulp penetration pressure and degree of external colouration bore no relation to storage regime directly after cold storage. Prior to storage, pulp penetration pressure and external colouration were in the order of 10,9 kg/A and 64,5% respectively. The values after cold storage differed little

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"Lenticel spot," often associated with chilling injury, was general to most of the fruit directly after cold storage, its occurrence bearing no relation to storage regime. On average, 87% (q 5.7%) of the fruit per carton showed noticeable spotting directly after cold storage, and 96% (q 2.7%) five days later when the fruit were firm-ripe.

All fruit showed a high degree of external colouration before and after cold storage. Before cold storage, degree of skin colouration was in the order of 64%. Directly after cold storage, degree of skin colouration generally decreased with increasing cold from 95% to a low of 65% (8/8/6/6), then increased to 78% (Fig. 17). Thus, ripening processes causing skin colouration occurred during cold storage at every regime. Five days later when the fruit were firm-ripe, variation in skin colouration due to storage regime was small, all fruit showing 100% colouration except for those stored at the coldest regime, where degree of skin colouration was in the order of 94%.

Percentage shriveled fruit per carton directly after cold storage bore no relation to storage regime, averaging 15 (q 12.7). This result seemingly indicates that shriveling depended on factors relating to the fruit itself rather than the relative humidity of the storage environment.

"Jelly seed" was the only physiological disorder observed. No relationship between the incidence of this disorder and storage regime was evident. On average, 18.8% (q 11.2%) of the fruit per carton showed visible symptoms of "jelly seed" when the fruit were firm-ripe.

Kent Seven days after cold storage when the fruit were firm-ripe, percentage marketable and good quality fruit per carton generally increased then decreased as the storage regime became colder (Fig. 18). The greatest quantity of marketable and good quality fruit was obtained when fruit were stored at the regime, 8/8/6/6. Here, 20% of the fruit per carton were of good quality and 44% marketable.

Pulp penetration pressure directly after cold storage increased inconsistently with increasing cold from 4.6 to 6.8 kg/A (Fig. 19), the differences between the regimes warmer than 11/11/11/11 and colder than 8/6/6/6 being relatively small.

Pulp penetration pressure before the fruit were placed in cold storage was in the order of 6.9 kg/A. Thus, ripening processes associated with fruit softening occurred at every regime except for the coldest regime. For the warmer regimes, the rates at which these processes took place were similar, except in the case of the warmest regime where the rate of softening during cold storage was greatest.

Following exposure of the fruit to room temperature, decay set in quickly, especially stem-end rot (Fig. 20), the percentage of fruit per carton showing symptoms decreasing linearly from 80 to 44 with increasing cold. The incidence of soft-brown rot, also largely responsible for the decay noted, first increased with increasing cold from 32% for the regime, 11/11/11/11, to 38% for the regime, 11/11/11/8, then decreased to a low of 22% for the regime, 8/8/6/6, before increasing to 32% for the
regime, 6/6/6/6. Symptoms of anthracnose rot were not apparent.

Percentage of fruit per carton showing stem-end rot directly after cold storage was very temperature dependent, decreasing rapidly from 30% for the regime, 11/11/11/11, to less than 10% for the regimes, 11/11/8/8 (colour: 70\% q 2.6%; pressure: 9.9 kglA, showing that processes causing fruit softening and skin colouration were retarded during cold storage.

Average skin colouration of the fruit per carton 14 days after cold storage decreased from 93% to a low of 79% (11/8/8/6), then increased to 85%, (Fig. 13). Reasons for this variation were unclear. It can be concluded, however, that fruit colouration did occur after cold storage regardless of storage regime.

Tommy Atkins Irrespective of storage regime, 60% (\% q 7.1%) of the fruit per carton were marketable and 41% (\% q 6.5%) of the fruit per carton were of good quality five days after cold storage when the fruit were firm-ripe.

Fig. 14 shows the variation due to storage regime of pulp penetration pressure directly after cold storage. As the storage regime became colder, pulp penetration pressure increased inconsistently from 0.6 to 5.0 kglA.

Pulp penetration pressure before the fruit were placed in cold storage was in the order of 7.7 kglA. Hence, ripening processes causing fruit softening occurred during storage at every regime, the extent of their action negatively correlating with the coldness of the storage regime.

Figure 9: Percentage of Zill fruit per carton showing soft-brown rot, anthracnose and stem-end rot directly after cold storage.

Figure 10: Percentage of noticeably shriveled Zill fruit per carton directly after cold storage.

Figure 11: Percentage of Sensation fruit per carton showing "jelly seed" after storage when the fruit reached the stage when firm ripe.

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Once the fruit were firm-ripe, decay due to anthracnose, stem-end rot and soft-brown rot was clearly evident (Fig. 15). A relationship between the type of decay present and storage regime seemed to exist. The percentage of fruit per carton visibly affected by soft-brown rot was high relative to stem-end rot and anthracnose for the regimes, 8/8/6/6 and colder. Percentages showing symptoms of anthracnose and soft-brown rot was high relative to stem-end rot for the regimes, 11/11/1/1, 11/11/1/8 and 11/11/8/8. The percentage of fruit per carton showing symptoms of stem-end rot was high relative to anthracnose and soft-brown rot for the regime, 11/8/8/6.

The high incidences of anthracnose and soft-brown rot for the warmer regimes seemed to reflect the ability of these rots and establish themselves during cold storage (Fig. 16), this ability relating to both degree of fruit softening and storage temperature. The high incidence of soft-brown rot for the colder regimes suggests a specificity in susceptibility of chill injured fruit to this type of decay. The high incidence of stem-end rot for the regime, 11/8/8/6, seemed to indicate that this type of rot could colonise harder fruit than anthracnose and soft-brown rot after cold storage, this ability relating to the fact that infection occurs at the site of the cut pedicle.

Figure 14: Pulp penetration pressure of Tommy Atkins directly after cold storage.
Figure 15: Percentages of Tommy Atkins fruit per carton showing soft-brown rot, anthracnose and stem-end rot after storage when the fruit reached the stage when firm-ripe.

Figure 16: Percentage of Tommy Atkins fruit per carton showing soft-brown rot, anthracnose and stem-end rot directly after cold storage. Analysis of variance was not performed due to marked variance heterogeneity between the means. Standard errors of the means ranged from 4.2 to 10.1%, 4.2 to 6.1% and 5.6 to 6.2% for soft-brown rot, anthracnose and stem-end rot respectively.
Since Kent has not been reported to be resistant to anthracnose, the absence of this disease may have been related to spaying in the field to prevent infection and/or packhouse treatments functioning to kill the causal organism. At the time the fruit were firm-ripe, the increase in the incidence of soft-brown rot for the regimes colder than 8/8/6/6 accompanied by a decrease in the incidence of stem-end rot is consistent with the findings for Irwin and Zill, indicating an increase in susceptibility for chill injured fruit to soft-brown rot, and a difference in etiology between stem-end rot and soft-brown rot.

Fruit stored at the regime, 8/6/6/6, showed least decay when firm-ripe. As in the case of the Irwin fruit, the greater incidence of decay of the fruit stored at the remaining regimes can be reasoned in terms of the level of decay directly after cold storage, and chilling injury to fruit stored at the regimes regime.

"Lenticel-spot" was general to most of the fruit, bearing no relation to storage regime. On average, 83% (q 6,0%) of the fruit per carton showed noticeable spotting directly after cold storage, and 95% (q 2,1%) five days later when the fruit were firm-ripe.

The percentage of shriveled fruit per carton bore no relation to storage regime, averaging 13 (q 5,2) directly after cold storage.

Figure 17: Skin colouration of Tommy Atkins directly after cold storage.

Degree of skin colouration directly after cold storage showed little variation with storage regime, averaging 17% (q 2,6%).

Degree of skin colouration before cold storage was in the order of 19%, showing that little to no colour change occurred during storage. Degree of skin colouration seven days after cold storage varied more greatly due to storage regime (Fig. 22), first decreasing from 70% to a low of 30,5%.

Figure 18: Percentage good quality and marketable Kent fruit per carton after storage when the fruit reached the stage when firm-ripe.

Figure 19: Pulp penetration pressure of Kent directly after cold storage.
(8/8/6/6) then increasing to 44%, as the storage regime became colder.

The foregoing results show that further skin colouration only occurred once the fruit were removed from cold storage. It would appear that a strong relationship existed between predisposition for colour development directly after cold storage and storage regime. Reasons for the relationship observed were unclear, however.

At the later time of evaluation, internal browning of the pulp was the only physiologically related disorder observed. No relationship with storage regime was evident, however. On average, 4.4% of (q 8.1%) of the fruit per carton showed internal browning.

Mean total soluble solids content of the fruit per carton bore no relation to storage regime when the fruit were firm-ripe, averaging 17% (q 0.4%).

Keitt The Keitt fruit were highly susceptible to chilling injury. Only after removing the fruit from cold storage did signs of injury become apparent, however. Directly after cold storage, 93% of the fruit per carton were of good quality and 97% (q 3.8%) of marketable quality irrespective of the regime at which the fruit were stored. Quality degrading was mainly due to the incidence of shriveling. Signs of decay were absent directly after cold storage.

Figure 20: Percentages of Kent fruit per carton showing stem-end rot and soft-brown rot after storage when the fruit reached the stage when firm-ripe.

"Lenticel spot" was general to most of the fruit directly after cold storage. On average, 99% (q 1.1%) were noticeably spotted.

Degree of skin colouration directly after cold storage bore no relation to storage regime, averaging 63% (q 3.0%). Degree of skin colouration before cold storage was of the same magnitude, showing that little or

Figure 21: Percentage of Kent fruit per carton showing soft-brown and stem-end rot directly after cold storage.

Figure 22: Skin colouration of Kent after storage when the fruit reached the stage when firm-ripe.
### Figure 23: Percentage good quality and marketable Keitt fruit per carton after storage when the fruit reached the stage when firm-ripe.

<table>
<thead>
<tr>
<th>Cold Regime</th>
<th>% Good Quality</th>
<th>% Marketable</th>
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### Figure 24: Percentage of chill injured Keitt fruit per carton after storage when the fruit reached the stage when firm-ripe.

<table>
<thead>
<tr>
<th>Cold Regime</th>
<th>% Cold Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1/1/1</td>
<td>100</td>
</tr>
<tr>
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<td>90</td>
</tr>
<tr>
<td>1/1/1/1</td>
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<tr>
<td>1/1/1/1</td>
<td>70</td>
</tr>
<tr>
<td>1/1/1/1</td>
<td>60</td>
</tr>
<tr>
<td>1/1/1/1</td>
<td>50</td>
</tr>
<tr>
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<td>40</td>
</tr>
<tr>
<td>1/1/1/1</td>
<td>30</td>
</tr>
<tr>
<td>1/1/1/1</td>
<td>20</td>
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<td>10</td>
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### General

The cultivars, Irwin, Kent, and Zill, are known to show little tolerance post-harvest decay in South Africa. Returns for exports of these cultivars during the 1988/89 growing season were reasonable, whereas returns were exceedingly poor during the 1989/90 growing season due to excessive post-harvest decay. Commercial export results during the 1988/89 growing season for the above stated cultivars correlated well with the results of this study. According to Pelser (1989), abundant sum-
mer rainfall during the period of fruit development and maturation renders summer conditions in South Africa very favourable for pre-harvest infection of Colletotrichum gloeosporioides and Hendersonia creberima. Wolstenholme and Mullins (1982) noted that rain, or even heavy dew, encourages the spread of Colletotrichum gloeosporioides.

Rainfall in many of the mango growing regions was far higher during the period from October to March 1988/89 than during the same period in 1987/88. For example, total rainfall recorded at "Die Eiland" during these months in 1988/89 was 291 mm, whereas during the same months in 1987/88, was 600 mm.

In mango and many other fruits, processes associated with ripening, e.g., softening and skin colouration, are preceded by a surge in ethylene production and a substantial rise in the respiration rate. The rates of ethylene production and respiration fall during subsequent ripening. These changes were clearly illustrated in "Golek" mango by Lam, Ng, Omar and Talib (1982). The characteristic rise in respiration rate is referred to as the respiratory climacteric, being part and parcel of the ripening process and marking the initiation of the many biochemical and physiological processes associated with ripening. Low temperatures are known to suppress or defer the progress of the climacteric in most fruits. Furthermore, too low a temperature may erase the ability to commence with the climacteric.

The Sensation fruit were least mature before being placed in cold storage, taking 14 days to ripen after storage at the various regimes. Moreover, during storage, processes causing softening and skin colouration were either severely retarded or did not occur irrespective of storage regime. Hence, it would appear that the Sensation fruit were in a pre-climacteric state before and during cold storage, the climacteric occurring subsequently.

The fruit of the remaining cultivars were more mature before cold storage. Softening was general during storage, the fruit ripening within a week thereafter. Hence, it would appear that these fruit were in a post-climacteric state during cold storage.

In view of the above, the conclusion might be reached that the climacteric will be deferred until after storage if fruit are picked soon enough and stored at any of the regime under study. Since post-harvest diseases generally develop only once softening commences, fruit not entering the climacteric before and during cold storage should not show signs of decay until after storage.

In Zill and Tommy Atkins, softening and colouration occurred during storage at every regime, whereas in Irwin, skin colouration and softening were halted at the colder regimes. The Kent fruit softened at every regime except for the coldest regime. Skin colouration was, however, halted at every regime. In Kent, skin colouration was halted regardless of storage regime, yet softening occurred at all regimes. In considering these responses to storage, it might be generalised that the ripening processes leading to fruit softening and skin colouration act independently of one another in mango.

Degree of softening during cold storage was generally greatest for fruit stored at the...
Anthracnose was most susceptible to Anthracnose and soft-brown rot, whereas fruit stored at the regimes slightly colder, showing greater susceptibility to stem-end rot.

In general, fruit stored at the coldest regimes, although showing little or no decay during storage, deteriorated rapidly afterwards. This fruit showed a high and specific susceptibility to soft-brown rot after storage. This was recognised to be the result of chilling injury. An increase in susceptibility to stem-end rot was, for the most part, not apparent, indicating the etiologies of stem-end rot and soft-brown rot to differ.

Figure 27: Percentage of Keitt fruit per carton showing anthracnose after storage when the fruit reached the stage when firm-ripe.

Fruit stored at the coldest regimes generally showed an increase in predisposition to post-storage skin colouration. In general, coldness of the storage regime and skin colouration, during and after storage, were negatively correlated. Hence, it would appear that the increase noted was a consequence of chilling injury.

"Lenticel spot" was general to the cultivars, Irwin, Tommy Atkins, Kent and Keitt, and bore no relation to storage regime. Moreover incidence of spotting increased during the post-storage period. According to Bragshaw and Brown (1989), this disorder can occur when fruit are held in dips, particularly if detergents have been added.

The variation in the percentage of fruit per carton showing noticeable shriveling for the cultivars, Irwin and Zill can be explained in terms of differences in relative humidity between the cold rooms. For the remaining cultivars, however, no relationship existed between the incidence of shriveling and storage regime. This seemed to indicate that, for these cultivars, shriveling depended on qualities of the fruit itself as opposed to the storage environment to which the fruit were exposed. Here, the occurrence of shriveling may have been related to the adequacy of waxing in the packhouse.

Figure 28: Pulp penetration pressure of Keitt directly after cold storage.

In all cultivars, the percentage of shriveled fruit per carton increased during the post-storage period. This seemed to result from continued dehydration in general.

For the cultivars, Kent and Keitt, storage regime had little or no effect on total soluble solids content when the fruit were firm-ripe. It might be concluded that starch conversion to simple sugars in these cultivars was as complete for the colder regimes as for the warmer regimes at ripening.

Only in the case of the physiological disorder, "jelly seed," did a relationship exist with storage regime, the incidence of this disorder increasing marginally with increases...
Figure 29: Total soluble solids content of Keitt directly after storage and when the fruit reached the stage when firm-ripe.
gimes giving rise to the best compromise yielded best results.

LITERATURE CITED


