Chapter V

DISCUSSION

5.1 Preservation of Fresh Lime Fruit by Controlled-Atmosphere Storage

The rate of O_2 uptake and CO_2 released of fresh lime fruits kept at $10^{o}C$ and 89% Relative Humidity under ordinary atmospheric condition can be seen in Table 1 and Figure 4. It is evident that the rate of O_2 uptake decreased rather rapidly at the initial stage and gradually decreased after 3 days. Similarly, the rate of CO_2 released decreased slowly throughout the experiment. These results confirm the findings of other investigators(32) that all citrus fruits are non-climacteric in nature.

The composition of atmosphere used in the storage has important effect on the keeping quality of the lime fruits at a fixed temperature and relative humidity.

Table 2 shows the effect of 10% O_2, 5% CO_2 on lime samples treated with 1000 ppm Benlate solution and kept at $10^{o}C$. The most obvious changes are % loss in weight, color of lime fruits and % spoilage after storage. The % loss in weight was not observed until after two months of storage time. However, from the 3^{rd} to 5^{th} month, the % loss in weight due to evaporation of water increased from 3.8 to 5.8%. Evidently, this small amount of moisture loss was mostly due to the result of good control of high % relative humidity in the experimental jar. Similary, the color change from the fresh green limes was not noticeable in the first month. More than 50% became yellowish-green after two months and changed completely to yellow color in the fourth month. The color change was due to degradation of chlorophyll and the formation of carotenoids. The color and appearance of lime fruit samples during storage can be seen in Figure 5-10 in the form of the whole and half section lime fruit. The general appearance of whole and half section samples of limes stored after 5 months were still fairly good. Taste panel results (see Table 3) indicated that the acceptability of the lime samples after storage for 4 months was 100%. Both the color and flavor were highly acceptable. For the lime samples after storage for 5 months, the acceptability was slightly decreased to 85%. Color as well as flavor of these lime samples were still acceptable. However, it was observed that after the 5th month, limes samples taken out of the experimental jar became dry, brown skin and developed off flavor after 5 days. However, for samples that stored in household refrigerator, the color and flavor were still acceptable even after 15 days storage.

The stored lime samples showed a considerable loss due to fungi (See Figure 11) eventhough they were treated with 1000 ppm of Benlate solution. It was possible due to the fungi within the porous structure of the skin even the harvest of fruits and the Benlate solution treatment was not able to penetrate deep enough to destroy them. The other components and chemical properties of lime namely pH, acidity, ascorbic acid content, total soluble solids, density, % volume of juice, and % weight of juice were changed only slightly during the entire 5 months storage period.

Table 4 shows the results using the same level of O_2 and CO_2 in the storage jar as the previous experiment (3.1.3.5) but using higher concentration of Benlate solution i.e.2000 ppm together with a surfactant (Air Product & Chemical's Surfynol T.G.). The objective of this experiment was to prove that the loss of limes as shown in Table 2 was not due to insufficient concentration of Benlate solution used but rather due to fungal origin. The results of % spoilage after storage in Table 4 appears to substantiate this proposition.

The effect of increase of CO_2 level while fixing the O_2 at 10%, 89% R.H. was investigated. The result of 10% O_2 and 30% CO_2 on the keeping quality of limes treated with 1000 ppm Benlate solution is tabulated in Table 5. The % loss in weight was similarly at a very low level of 2.4% after 3 months storage. The other quality attribute also showed very little variation for the first two months. The green color of the lime fruits was unchanged for the first month and changing to yellowish-green to a small extent (25%) after 2 months. Nevertheless, it turned to brown color and caused complete damage of fruit after 3 months (See Figure 12). The damaged lime became soften and the juice color was slightly brown and developed undesirable flavor. It is theorized that high CO_2 level probably interfered with normal metabolic activity leading to abnormal respiration process causing toxic substances such as alcohol and other toxic end products to accumulate and damaged the fruits (4,33).

Table 6 shows the influence of 10% O_2, 15% CO_2 at 10^oC and 89% R.H. on the quality of limes. It was evident from the results that despite the fact that CO_2 level was reduced from 30% to 15%, the % CO_2 used was still far too high as indicated by the complete damage of lime samples only after $1\frac{1}{2}$ months. Experiment was repeated with the same conditions and almost the same results were obtained as shown in Table 7.

The effect of atmospheric condition at 5% O_2, 5% CO_2 at 10^oC and 89% relative humidity on the quality of lime is tabulated in Table 8. It can be seen that % loss in weight was 1.1 and 4.1 after 2 and 5 months respectively. The amount of water loss was not much different from the other experiments. The color of lime was changed from green to yellowish-green, greenish-yellow and yellow in different percentages after the 3^{rd} month and completely changed to yellow color in the 5^{th} month. The percentage spoilage of stored lime was 50% after storage for one month and 28% in the 4^{th} month. These high percentages of spoilage were similarly due to fungi. The total spoilage of limes was much higher than in the case of 10% O_2 and 5% CO_2 (See Table 2). The other constituents and chemical properties changed only to a small extent as in all other experiments.

5.2 Lime Juice Concentrate Processing

Table 9 shows that a considerable amount of ascorbic acid content was destroyed during evaporation process. The percent loss of ascorbic acid was 9.78%. The color of the concentrated juice was slightly brown in contrast with the greenish-yellow color of freshly extracted juice due to browning reactions. The brown color occurred as a result of Maillard reaction (35) or Ascorbic acid browning reaction (38, 39,43). The intensity of aroma and taste of concentrated juice were reduced to a small extent because of evaporation of some volatile substances during the vacuum evaporation process.

Total soluble solid

Table 10 shows that total soluble solid was not affected by storage temperature and time of storage.

Total acidity

From Table 11 it is evident that storage time, storage temperature and addition of potassium metabisulfite had very little effect on the total acidity of the concentrated lime juice. Potassium metabisulfite had also no influence on the total acidity of the concentrated lime juice which coincides with the findings of Shaker et al (52).

pH value

Similarly, pH of the concentrated lime juice with or without addition of potassium metabisulfite did not change (Table 12) when stored at room and refrigerated temperature for different storage time, this result is in accordance with the report of Heikal et al.(51).

Ascorbic acid

The loss of ascorbic acid occurred in concentrated lime juice samples stored at different temperature and for a different period of time. In addition, potassium metabisulfite was found to be effective in retaining the ascorbic acid content. From table 13, it can be seen that the loss of ascorbic acid in samples without addition of potassium metabisulfite was from 5.88 to 33.4% in a period of 14 weeks at room temperature while the loss was from 2.65 to 28.03% for samples stored at 10^{o}C.

For samples with addition of 300 ppm potassium metabisulfite, less loss of ascorbic acid was encountered i.e. 3.44 to 23.91% for samples at room temperature and 3.05 to 17.9% at 10^{o}C. It can be concluded from this experiment that storage of concentrated lime juice at high temperature will result greater loss of ascorbic acid and the addition of additive such as potassium metabisulfite will help in better retention of ascorbic acid.(35)

Optical density

The color of the concentrated lime juice is an important attribute, as it is a good indicator of the juice quality. To follow the change of juice color during storage, spectrophotometric method was used to measure the % optical density (Result as seen in Table 14).

In addition, the effect of storage temperature and storage time on development of browning of concentrated lime juice was also checked by visual inspection as shown in Table 15. It was found that at room storage temperature, the concentrated lime juice samples without potassium metabisulfite developed color change fairly rapidly as brown color could be clearly seen after 2 weeks. On the contrary, the samples with potassium metabisulfite showed only slight brown color even after $3\frac{1}{2}$ months of storage at room temperature.

For sample stored at 10°C, it was shown that low temperature alone was not very effective in retarding the color change as it is exemplified by the fact that samples without potassium metabisulfite stored at temperature of 10°C developed brown color only after one month, which was faster than the concentrated lime juice samples stored at room temperature but with addition of potassium metabisulfite. However, the combination of low temperature storage and the use of additive will give the best result as shown by the samples with addition of potassium metabisulfite and kept at 10°C. The color did not change even after $3\frac{1}{2}$ months storage time.

Flavor

The results of the concentrated lime juice flavor evaluated organoleptically by teste panel were shown in Table 16.

It was found that the concentrated lime juice without potassium metabisulfite and stored at room temperature developed undesirable flavor after two months while those samples kept at 10°C were favourably accepted for as long as 3 months. The flavor of concentrated lime juice with potassium metabisulfite was still acceptable after $3\frac{1}{2}$ months for samples both at room temperature and refrigerated temperature (10°C).

The development of undesirable flavor was probably caused by the oxidation of limonene which occurred at high temperature storage (46). In addition, reaction products resulting from browning reaction might play a part in the development of off-flavor.