

Chapter IV -

EXPERIMENTAL RESULTS

4.1 Preservation of Fresh Lime Fruit by Controlled- Atmosphere Storage

4.1.1 The Study of rate of O₂ Uptake and CO₂ Released

The results are shown in Table 1 and Figure 4. The total weight of 47 fresh lime fruits used in the experiment are 1.93 kilograms.

4.1.2 Effect of 10% O₂, 5% CO₂ at 10°C and 89% R.H. on the fresh lime fruits treated with 1000 ppm Benlate solution.

The experimental results are shown in Table 2,3 and Figure 5-11

4.1.3 Effect of 10% O₂, 5% CO₂ at 10°C and 89% R.H. on the lime fruits treated with 2000 ppm Benlate solution.

The results of the experiment are shown in Table 4.

4.1.4 Effect of 10% O₂, 30% CO₂ at 10°C and 89% R.H. on the lime fruits treated with 2000 ppm Benlate solution

The following results are shown in Table 5, and Figure 12.

Table 1

Rate of O₂ up-take and CO₂ released at 10°C and
89% R.H.

days	% O ₂ , ^v / _v	ml O ₂ up- take kg-hr	% CO ₂ , ^v / _v	ml CO ₂ released kg-hr
0	18.2	-	0	0
1	16.8	5.8	1.0	4.2
2	15.5	4.2	2.0	4.2
3	15.0	2.1	2.8	3.3
4	14.5	2.1	3.6	3.3
5	14.2	1.3	3.0	2.5
6	14.0	0.8	3.7	2.9
7	13.8	0.8	4.3	2.5
8	13.5	1.3	4.8	2.1
9	13.2	1.3	5.2	1.7
10	12.9	1.3	5.5	1.3
11	12.6	1.3	6.0	2.1
12	12.2	1.7	6.2	0.8
13	11.9	1.3	6.5	1.3
14	11.5	1.7	6.7	0.8
15	11.3	0.8	7.0	1.3

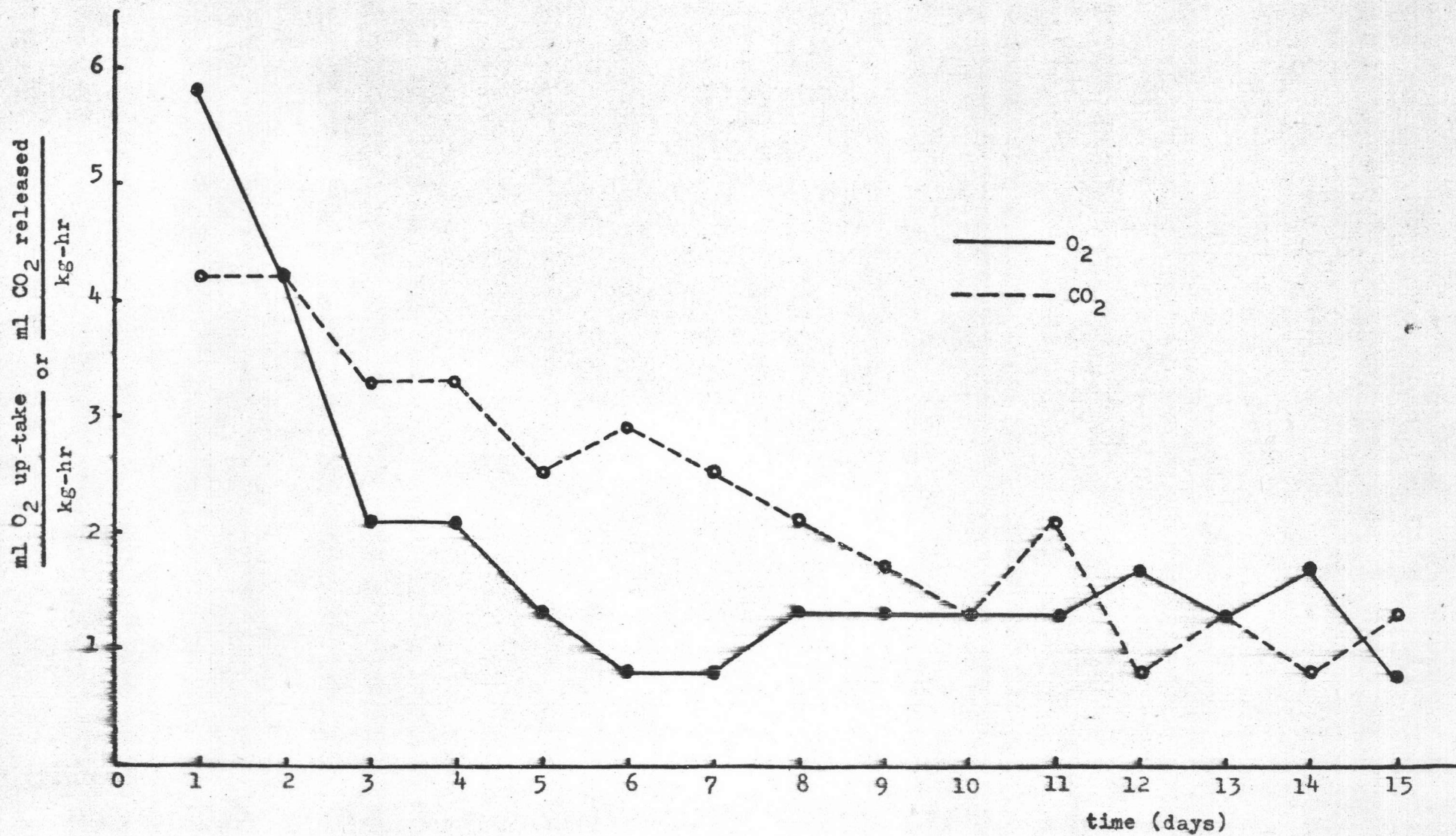


Figure 4 Rate of O₂ up-take and CO₂ released at 10°C and 89% R.H.

Table 2

Effect of 10% O₂, 5% CO₂ at 10°C and 89% R.H. on the fresh lime fruits treated with 1000 ppm Benlate solution

storage time (month)	% loss in wt. based on av. fresh lime wt.	change in color (%)				av.wt. of fruit (g)	% wt. of juice	% V. of juice	den- sity of juice	pH	TSS °B	acidi- ty % as citric acid	ascor- bic acid mg/100ml	% spoi- lage after stor- age
		G	YG	GY	Y									
0	0	100	0	0	0	38.5	34.7	33.3	1.04	2.2	8.0	7.5	35.2	0
1	0	100	0	0	0	49.0	33.9	32.5	1.05	2.2	8.0	7.7	32.0	9.7
2	0	45	55	0	0	43.5	35.8	34.4	1.04	2.2	8.5	7.4	35.2	15.4
3	3.7	0	47	53	0	46.0	34.2	32.9	1.04	2.3	7.9	7.5	32.3	7.3
4	4.6	0	0	0	100	42.5	35.8	34.8	1.03	2.15	7.0	6.3	31.7	4.5
4½	4.8	0	0	0	100	44.0	35.2	34.3	1.03	2.5	7.6	7.7	29.6	0
5	5.8	0	0	0	100	47.0	34.0	32.9	1.03	2.5	8.4	6.7	30.2	0

Table 3

Panel taste score of lime sample after storage in
10% O₂, 5% CO₂ at 10°C and 89% R.H. for 4 and 5 months

Storage time	skin, color of fresh lime	Flavor of lime juice	Accepta- bility
4 months	8.4	7.4	100 %
5 months	6.5	5.5	85 %



Figure 5 Fresh Lime Fruit at the Beginning of the Experiment



Figure 6 Lime Fruit After Storage for 4 months

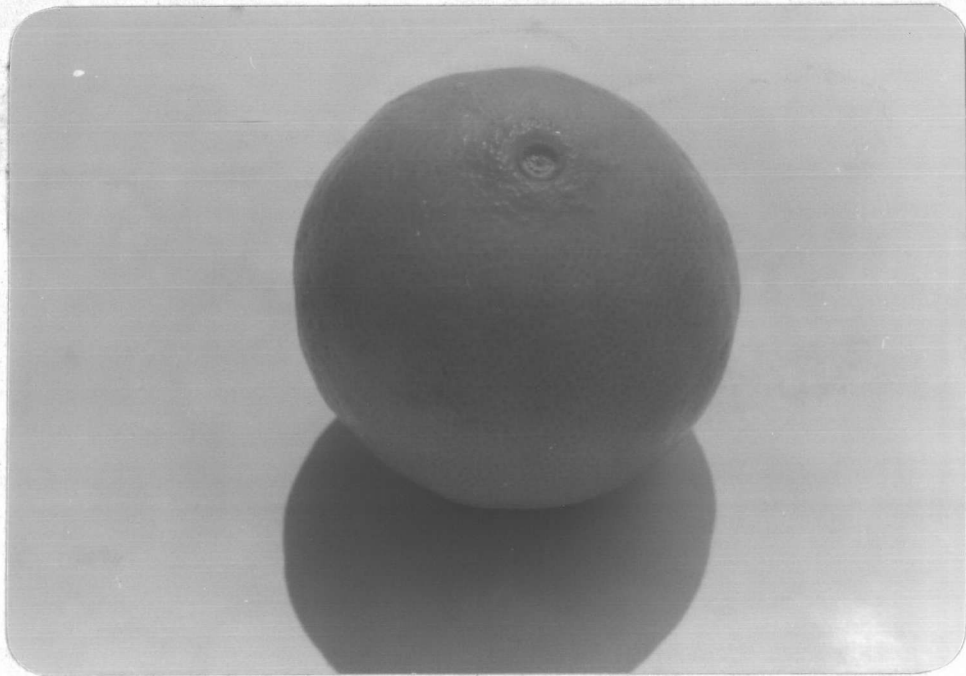


Figure 7 Lime Fruit After Storage for 5 months

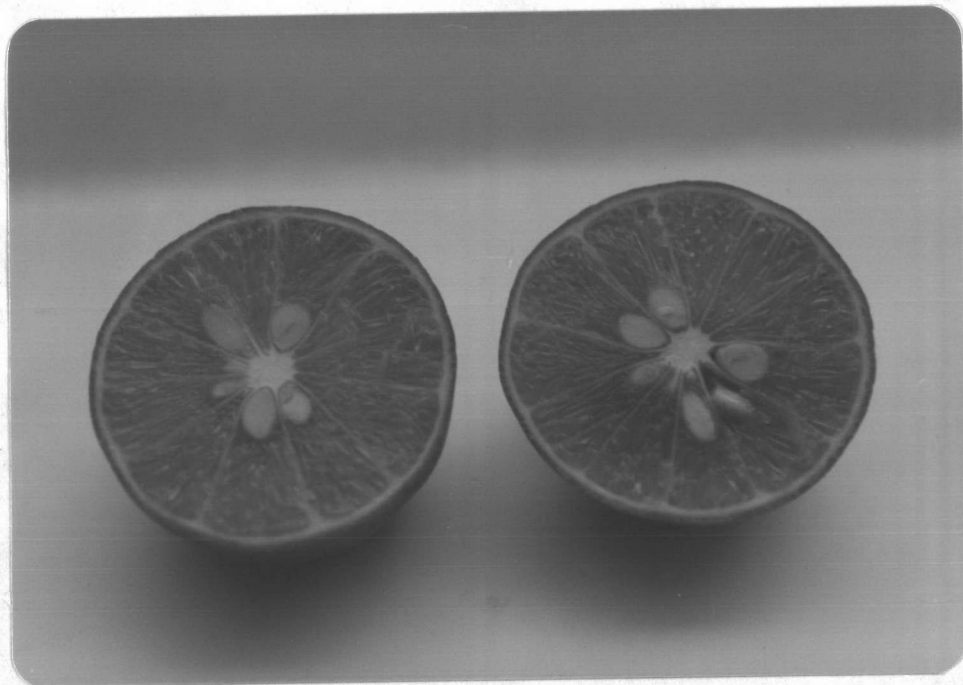


Figure 8 Halved Fresh Lime Fruit at the Beginning
of the Experiment

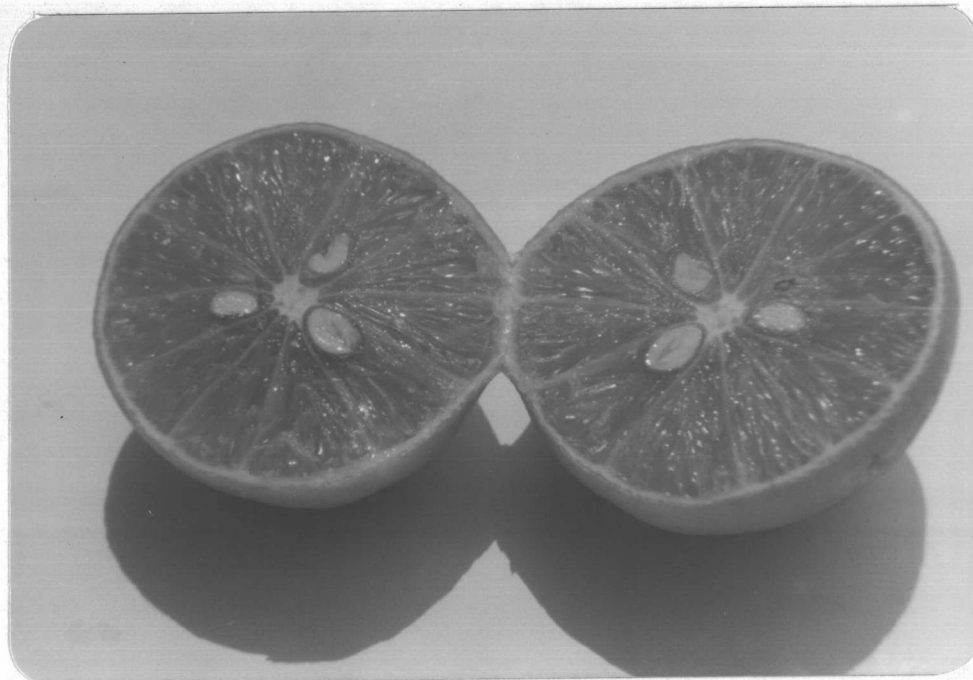


Figure 9 Halved Lime Fruit After Storage for
4 months



Figure 10 Halved Lime Fruit After Storage for
5 months



Figure 11 Typical Damaged Lime Fruit Sample
due to Fungi

Table 4

Effect of 10% O₂, 5% CO₂ at 10°C and 89% R.H. on the fresh lime fruits treated with 2000 ppm Benlate solution

stor- age time (mon. ths)	% loss in wt based on av. fresh lime wt.	change in color (%)					av. wt. of fruit (g)	% wt.of juice	% vol. of juice	den- sity of juice	pH	TSS °B	acidi- ty % as citric acid	ascor- bic acid mg/ 100 ml	% Spoi- lage after stor- age
		G	YG	GY	Y	B									
0	0	100	0	0	0	0	43.0	33.7	32.3	1.04	2.2	8.1	7.6	32.8	0
1	0	100	0	0	0	0	43.5	33.8	32.2	1.05	2.2	8.4	7.2	32.4	45.8
2	0	54	46	0	0	0	39.3	36.2	34.6	1.05	2.5	8.0	6.7	29.1	5.5
3	2.2	18	52	30	0	0	32.3	41.4	40.9	1.01	2.3	7.8	6.5	29.5	1.8
4	3.1	0	0	43	57	0	31.0	41.9	41.3	1.01	2.5	8.0	6.6	27.3	5.5
5	5.6	0	0	0	100	0	37.5	39.5	38.1	1.04	2.5	8.1	6.5	27.1	0

Table 5

Effect of 10% O₂, 30% CO₂ at 10°C and 89% R.H. on the fresh lime fruits treated with 1000 ppm Benlate solution

stor- age time (mon- th)	% loss in wt. based on av. fresh lime wt.	change in color (%)					av. wt. of fruit (g)	% wt. of juice	% V. of juice	densi- ty of juice	pH	TSS °B	aci- dity % as citric acid	ascor- bic acid mg/ 100 ml	% spoi- lage after stor- age
		G	YG	GY	Y	B									
0	0	100	0	00	0	0	46.5	33.4	32.3	1.04	2.1	8.0	7.5	35.2	0
1	0	100	0	0	0	0	43.5	33.1	31.1	1.06	2.4	7.8	7.8	30.3	0
2	0	75	25	0	0	0	47.5	34.5	33.4	1.03	2.2	7.9	7.9	32.3	22.5
3	2.4	0	0	0	0	100	45.0	30.0	27.9	1.08	2.4	7.8	5.4	28.8	77.5

1



2



Figure 12 Typical Damaged Lime Fruit Sample due
to CO₂ Injury

1 - whole lime fruit

2 - cut section of lime fruit

Table 6

Effect of 10% O₂, 15% CO₂ at 10°C and 89% R.H. on the fresh lime fruits treated with 1000 ppm Benlate solution

stor- age time (mon th)	% loss in wt. based on av. fresh lime wt.	change in color (%)					av. wt. of fruit (g)	% wt. of juice	% V. of juice	den- sity of juice	pH	TSS °B	acidi- ty as % citric acid	ascor- bic acid mg/ 100 ml.	% spoi- lage: after stor- age
		G	YG	GY	Y	B									
0	0	100	0	0	0	0	40	41.7	40.0	1.05	2.2	8.4	7.5	30.9	0
1	0	75	0	0	0	25	44	42.5	40.9	1.04	2.2	8.2	7.0	28.3	25
1½	0	0	0	0	0	100	37.5	40.0	38.6	1.03	2.6	7.7	6.4	25.7	75

Table 7

Effect of 10% O₂, 15% CO₂ at 10°C and 89% R.H. on the fresh lime fruits treated with 1000 ppm Benlate solution

stor- age time (mon- th)	% loss in wt. based on av. fresh lime wt.	change in color					av. wt. of fruit (g)	% wt. of juice	% V. of juice	den- sity of juice	pH	TSS °B	aci- dity as % citric acid	ascor- bic acid mg/ 100ml	% spoi- lage after stor- age
		G	YG	GY	Y	B									
0	0	100	0	0	0	0	36	41.5	38.5	1.08	2.2	8.0	7.8	33.7	0
1	0	100	0	0	0	0	39	42.3	41.3	1.02	2.2	8.2	7.8	30.2	0
2	2.7	63	0	0	0	37	40	40.2	38.3	1.05	2.4	7.9	6.9	28.6	23.3
2½	4.6	0	0	0	0	100	43	38.7	36.7	1.05	2.6	7.5	6.2	27.3	76.7

Table 8

Effect of 5% O₂, 5% CO₂ at 10°C and 89% R.H. on the fresh lime fruits treated with 1000 ppm Benlate solution

stor- age time (mon- th)	% loss in wt. based on av. fresh lime wt.	change in color (%)					av. wt. of fruit (g)	% wt. of juice	% V of juice	den- sity of juice	pH	TSS °B	acidi- ty as % citric acid	ascor- bic acid mg/ 100ml	% spoi- lage after stor- age
		G	YG	GY	Y	B									
0	0	100	0	0	0	0	34.0	41.1	39.1	1.05	2.2	8.2	7.5	30.1	0
1	0	100	0	0	0	0	36.0	41.4	39.3	1.05	2.4	8.2	7.3	30.2	50.0
2	1.1	62	38	0	0	0	32.5	36.7	35.8	1.03	2.4	8.0	7.02	29.2	0
3	2.7	0	22	45	33	0	36.5	42.5	41.8	1.02	2.4	7.8	6.9	29.3	4.7
4	2.9	0	0	15	85	0	32.0	40.7	39.6	1.03	2.38	7.2	6.3	29.5	28.0
5	4.1	0	0	0	100	0	38.0	37.3	36.5	1.02	2.5	7.6	6.4	27.4	0

4.1.5 Effect of 10% O₂, 15% CO₂ at 10°C and 89% R.H. on the fresh lime fruits treated with 1000 ppm Benlate solution

The experimental data are shown in Table 6 and 7

4.1.6 Effect of 5% O₂, 5% CO₂ at 10°C and 89% R.H. on the fresh lime fruits treated with 1000 ppm Benlate solution

The results of the experiment are shown in Table 8.

4.2 LIME JUICE CONCENTRATE PROCESSING

4.2.1 Quality of Lime Juice

The physical and chemical properties of fresh lime juice and concentrated lime juice are shown in Table 9

Table 9

Physical and Chemical Properties of Fresh Lime Juice and Concentrated Lime Juice

Quality factors	Fresh lime juice	Concentrated lime juice
Total soluble solid °Brix	6	30
Acidity (mg/100 ml)	7.32	32.7
Ascorbic acid (mg/100 ml)	28.71	128.50
% Ascorbic acid loss	-	9.78
Color	normal	slightly brown
Flavor	very good	good

4.2.2 Effect of Storage Temperature and Storage Time on Quality
of Concentrated Lime Juice

The effect of storage temperature and storage time on total soluble solids, total acidity, pH, ascorbic acid content, optical density, color and flavor of concentrated lime juice are shown in Table 10-16

Table 10

Effect of storage temperature and storage time on total soluble solids ($^{\circ}$ Brix) of concentrated lime juice

Storage time (Week)	Total soluble solids, $^{\circ}$ Brix			
	Room temperature (28 $^{\circ}$ C)		10 $^{\circ}$ C	
	Control	with addition of 300 ppm K ₂ S ₂ O ₅	Control	with addition of 300 ppm K ₂ S ₂ O ₅
0	24.3	24.4	24.3	24.4
2	24.0	23.0	24.0	24.0
4	23.0	23.0	23.0	23.0
6	23.5	23.7	28.7	23.4
8	24.5	24.0	24.0	24.0
10	23.2	23.2	23.5	22.7
12	23.3	22.5	23.2	22.7
14	23.6	23.2	23.8	23.6

Table 11

Effect of storage temperature and storage time on total acidity of concentrated lime juice

Storage time (Week)	Total acidity, % as citric acid			
	Room temperature (28°C)		10°C	
	Control	with addition of 300 ppm $K_2S_2O_5$	Control	with addition of 300 ppm $K_2S_2O_5$
0	29.42	27.97	27.42	27.97
2	26.86	26.32	27.74	26.97
4	27.00	27.00	26.64	27.38
6	27.30	26.70	27.29	26.21
8	27.25	26.74	26.29	26.83
10	27.29	27.12	27.30	27.01
12	26.57	27.32	26.19	27.74
14	27.48	27.02	27.74	27.13

Table 12

Effect of storage temperature and storage time on pH value of concentrated lime juice

Storage time (Week)	pH value			
	Room temperature (28°C)		10°C	
	Control	with addition of 300 ppm $K_2S_2O_5$	Control	with addition of 300 ppm $K_2S_2O_5$
0	2.1	2.1	2.1	2.1
2	2.1	2.2	2.2	2.2
4	2.4	2.3	2.25	2.3
6	2.2	2.15	2.1	2.2
8	2.2	2.2	2.2	2.2
10	2.2	2.2	2.2	2.2
12	2.2	2.2	2.2	2.2
14	2.2	2.2	2.2	2.2

Table 13

Effect of storage temperature and storage time on ascorbic acid content of concentrated lime juice

Storage time (week)	Storage temperature							
	Room temperature (28°C)				10°C			
	Control		with addition of 300 ppm $K_2S_2O_5$		Control		with addition of 300 ppm $K_2S_2O_5$	
	ascorbic acid mg/100ml	% ascorbic acid retention	ascorbic acid mg/100ml	% ascorbic acid retention	ascorbic acid mg/100ml	% ascorbic acid retention	ascorbic acid mg/100ml	% ascorbic acid retention
0	109.09	100.00	108.42	100.00	109.09	100.00	108.42	100.00
2	102.60	94.12	104.70	96.56	106.20	97.35	105.12	96.95
4	91.39	87.77	100.30	92.51	98.43	90.23	103.08	95.07
6	103.00	94.49	98.10	90.50	104.16	95.48	104.56	96.43
8	97.40	89.20	91.83	84.73	97.38	89.26	100.75	92.92
10	89.10	81.74	86.97	80.22	90.70	83.14	102.80	94.85
12	80.68	73.41	94.30	86.97	88.25	80.90	95.30	87.35
14	72.70	66.60	82.50	76.09	79.60	79.97	89.00	82.09

Table 14

Effect of storage temperature and storage time on percent of optical density at $410\text{ m}\mu$ of concentrated lime juice

Storage time (week)	Optical density			
	Room temperature (28°C)		10°C	
	Control	with addition of 300 ppm $\text{K}_2\text{S}_2\text{O}_5$	Control	with addition of 300 ppm $\text{K}_2\text{S}_2\text{O}_5$
0	48.5	49.0	48.5	49.0
2	57.5	49.0	49.0	49.0
4	54.0	52.5	51.0	51.0
6	59.0	47.0	54.0	44.0
8	75.0	53.0	57.0	48.5
10	90.7	61.0	69.0	53.0
12	97.0	53.0	86.0	53.0
14	96.0	65.0	83.0	54.0

Table 15

Effect of storage temperature and storage time on development of browning of concentrated lime juice

Storage time (week)	Development of browning			
	Room temperature (28°C)		10°C	
	Control	with addition of 300 ppm $K_2S_2O_5$	Control	with addition of 300 ppm $K_2S_2O_5$
0	0	0	0	0
2	+	0	0	0
4	++	0	+	0
6	+++	0	+	0
8	++++	0	++	0
10	+++++	0	+++	0
12	++++++	0	+++	0
14	++++++	+	++++	0

Table 16

Average taste panel score of concentrated lime juice during storage test.

Storage time (week)	Average taste panel score			
	Room temperature (28°C)		10°C	
	Control	with addition of 300 ppm $K_2S_2O_5$	Control	with addition of 300 ppm $K_2S_2O_5$
0	6.8	6.2	6.8	6.2
2	5.5	5.7	6.2	5.9
4	5.7	5.7	6.0	5.7
6	4.9	5.8	5.8	5.9
8	4.0	5.1	5.0	5.6
10	-	4.9	5.4	5.8
12	-	5.4	5.1	5.4
14	-	5.0	4.7	5.7