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Quality attributes of Bearss Seedless lime (*Citrus latifolia Tan*) juice during storage

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Abstract

Fruits of Bearss Seedless lime (*Citrus latifolia Tan*) were divided into two grades according to the degree of maturity on tree (i.e. Grade A, dark green and Grade B, light greenish yellow). Fruit weight, colour and dimensions were assessed. Fruits of each grade were subjected to hand-peeling, juice extraction, filtration and removal of bitterness by adsorption using cellulose acetate (2%). Pasteurized juices (91°C/15 s) were stored in glass bottles under refrigeration (5 ± 1°C) and freezing (−20 ± 1°C) for 30 weeks. The juice yield, specific gravity, crude protein, amino acids, ash, P, Na, K, Ca and Fe were determined at zero time, while Brix°, pH, titratable acidity, ascorbic acid, reducing and total sugars, browning index, colour and sensory evaluation of juices were assessed at 3 week intervals. The juices had 55.6 and 59.4% yield; 9.48 and 9.82% dry matter, 0.365 and 0.380% protein; 0.322 and 0.329% ash, for A and B grades, respectively. During storage, the pH-value, ascorbic acid and total sugars decreased gradually, while reducing sugars, titratable acidity, browning index and ΔE for colour were found to increase gradually. The changes were higher for B grade than A and for refrigerated juices more than frozen ones. Sensory evaluation of juices revealed that refrigerated juices were accepted for up to 27 and 21 weeks for A and B grades, respectively. Frozen juices were acceptable up to the end of the experiment.

1. Introduction

Citrus is considered as one of the important fruit crops in tropical and sub-tropical regions. The United States Department of Agriculture reported that Egypt ranks tenth in the production of citrus, but second in lime production (El-Helaly, 1995). However, data on the composition and quality of lime fruits produced in Egypt are scarce. Lime juice is widely consumed in different forms, namely as condiments, as flavouring materials especially for some hot cooked foods and vegetable salads, as an acidulant and in the manufacture of lemonade. It is also used for preventing darkening in the fresh fruits that used in syrup manufacture and applied in pickle brine (Carter, 1993).

Lime juice has the following chemical composition: total soluble solids (10%); total acidity (5.1–7.7%); protein (0.24–0.50%); ash (0.4%); ascorbic acid (39–62 mg/100 ml); total invert sugar (0.69–0.72%), and non-reducing sugar (0.14–0.20%); specific gravity ranges between 1.026 and 1.039 g/ml and pH of the lime juice varies from 1.7 to 3.2 (Simmonds, 1984; Swisher & Swisher, 1980). Fifteen to seventeen free amino acids have been detected in lime juice (Ali, 1996; Fernandez-Flores, Kline & Johnson, 1970).

Citrus juices undergo a number of deteriorative reactions during storage at room temperature. Such reactions result in the development of off-flavour and browning (Kimura, Nishimura, Iwata & Mizutani, 1983; Grosch & Schieberle, 1987; Kacem, Cornell, Marshall, Shireman & Matthew, 1987; Kacem, Matthews, Crandall & Cornell, 1987). The flavour impact compound of lime is germacrene B (Shaw, 1996). Notwithstanding, bitterness in citrus can be primarily attributed to either limonin or the flavanone glycoside, naringin or a combination of the two (Nagy & Rouseff, 1980). Several physical and biochemical methods have been proposed to reduce bitterness in processed citrus juices. According to Ali (1996), adsorption on cellulose acetate was found to quite satisfactory in this respect.

Ascorbic acid is highly sensitive to changes in the environment such as, pH, oxygen and enzyme (de Man, 1990). When 15% decrease in ascorbic acid occurs, lime juice is subject to browning (Curl & Talburt, 1961). Moreover, 5-hydroxy methyl furfural and furfural are found to be highly significantly correlated with browning index (Robertson & Samaniego, 1986). Consequently, ascorbic acid, reducing sugars, amino acids and probably other carbonyl compounds can be considered as an integral part of the browning system (Ali, 1996).

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Although the Bearss Seedless lime (*Citrus latifolia Tan*) was introduced to Egypt by the Desert Development Centre (DDC) belonging to the American University in Cairo (AUC) since 1985, no information is available regarding its quality attributes. Accordingly, the present work was carried out to assess such attributes and to investigate the shelf life of the juice under different conditions.

2. Material and methods

2.1. Material

Bearss Seedless lime (*Citrus latifolia Tan*) was obtained from the Desert Development Centre (DDC), South Tahrir Station, American University in Cairo (AUC) in January 1996.

2.2. Methods

2.2.1. Bearss Seedless lime fruits

Fruits were divided into two grades according to the degree of maturity. Grade (A) included the dark green fruits (D colour as Harding, Winston & Fisher, 1940) and grade (B) included the light greenish yellow fruits (F colour as Harding et al., 1940). Each grade was counted and weighed, then the fruits/kg were calculated. Twenty-five fruits, from each group, were taken for determining the weight and dimensions of such fruit, then the means of fruit weights and dimensions were calculated. The colour of fruits was assessed by using the Lovibond Schofield Tintometer (The Tintometer Ltd, UK). The Tintometer readings were further converted into C.I.E units using the visual density graphs supplied with the apparatus.

2.2.2. Bearss Seedless lime juices

2.2.2.1. Preparation of juices. Fruits were peeled manually and the juice was extracted by using a Multiple automatic Braun, NIP 80, Germany. The juices were weighed and the yield was calculated by dividing the weight of juice by the weight of the fruits $\times 100$. The resultant juice was rapidly strained through a cheese cloth and stainless steel sieve with pore diameter of 125 μm to accomplish separation of most of the suspended matter from the juice. Cellulose acetate (CA), Sigma Chemical Co. (2%) was used as absorbent for bitterness, as recommended by Ali (1996). The mixture of juice and CA was stirred for 1 h and filtered through a cheese cloth. The resultant filtrate was pasteurized at 91°C for 15 s, they cooled rapidly.

2.2.2.2. Physical properties. The specific gravity of juice was measured using a pycnometer while the colour of the juice was assessed by the Lovibond Schofield Tintometer as described above. The total soluble solids (TSS) were determined by using an ATAGO/Smill Refractometer. The method of Meydav, Saguy and Kopelman (1977) for the browning index determination was used and the optical density of the filtrate was read at 420 nm by a Spectronic 20 D^+, Spectronic Instruments, Inc.

2.2.2.3. Chemical methods. Crude protein ($N \times 6.25$) was determined by the semimicro Kjeldahl method (Egan, Kird & Sawyer 1981). Ash was determined by igniting a weighed sample in a muffle furnace (Gallenkamp KM 106 GKP 172) at 550°C to a constant weight (AOAC, 1990). Total phosphorus was determined colorimeterically. Sodium and potassium were determined by flame photometer (Gallenkamp, UK) while calcium and iron were determined by atomic absorption (Pye Unlearn SP 1900) as outlined by AOAC. Free amnino acids were determined using a Beckman Amino Acid Analyzer (Model 114 CL) as outlined by Kacem, Matthews et al. (1978). The pH-value was measured using a Digital pH-meter (HANNA Instruments, HI 9321 Microprocessor pH-meter, Portugal). The total titratable acidity was assessed by titration with sodium hydroxide (0.1 N) and expressed as % citric acid. Ascorbic acid was determined using 2,6-dichlorophenolindophenol by visual titration (AOAC, 1990). Reducing sugars were determined using the Nelson–Somogyi micro colorimetric method while total sugars were assessed by using the phenol-sulphuric method as outlined by Southgate (1976).

2.2.2.4. Storage stabiltity. The pasteurized juice was stored in glass bottles under refrigeration (5 ± 1°C) and freezing (-20 ± 1°C) conditions. The storage was monitored by evaluating each of the following: Brix°, pH, titratable acidity, ascorbic acid, reducing sugars, total sugars and browning index, as outlined above. Moreover, ΔE (the distance, cm, between the point of a given sample and a given time and the point of the colour of juice at zero time on the visual density graph) was assessed according to Ziena, Youssef and Aman (1997). The stored juices were also evaluated by panellists who were asked to rank the samples as hedonic scales of 10 points regarding each, sourness, bitterness, colour and overall acceptability.

2.2.2.5. Statistical analysis. Data of chemical composition were subjected to analysis of variance and Duncan's Multiple Range test to separate the treatment means as outlined by Steel and Torrie (1980).

3. Results and discussion

Table 1 reveals that the marketable Bearss Seedless lime fruits in Egypt have dimensions between 6.2×2.5

cm and 7.5×6.5 cm. In contrast, the Egyptian common lime (known locally as *Banzahir* and *Houssei* lime) is usually smaller in size (about 3.75 cm in diameter) as reported by El-Helaly (1995). The means of fruit weight were 82.6 and 84.8 g for the two grades A and B, respectively. The juice yield and specific gravity (g. ml^{-1}) for grade B were markedly higher than grade A due to the small size of grade A. On the other hand, total soluble solids were found to increase as ripening proceeded. However, the juice yields for the two grades were over 50% as compared to 35% in Egyptian Balady (*Banzahir*) lime (*Citrus aurantifolia*) as reported by Ali (1996). The colour of fruits and their juices showed variations, depending on ripening grade, and so the dominant wavelengths were 567 and 577 nm for fruits while they were 570 and 573 nm for juices from A and B grades, respectively.

3.1. Chemical composition of juice

In general, the total soluble solids (Brix°), protein (N×6.25), ash and minerals were significantly higher for grade B than grade A (Table 2). This variation can be explained on the basis of the accumulation and/or synthesis processes during fruit development on the tree. In accordance, Ali (1996), Simmonds (1984) and Swisher and Swisher (1980) published quite comparable data in this regard.

Amino acid composition of tested lime juices is shown in Table 3. The main amino acids were arginine, aspartic and glumatic acids, while minor ones were methionine, leucine and isoleucine. Ali (1996) reported that the main amino acids in Egyptian Balady (*Banzahir*) lime juice were aspartic and glutamnic acids followed by arginine, threonine + serine and alanine.

3.2. Storage stability

The pH-value of fresh lime juice extracted from B-grade fruits was lower than that for A (Table 4). However, the pH values of lime juices were generally found to decline during storage. The percentage decreases were 7.3 and 1.1% for grade A and 8.7 and 1.7% for grade B, for refrigerated and frozen juice, respectively. The declines were significantly higher for refrigerated juices than frozen ones.

Table 1
Some physical characteristics of Bearss Seedless lime samples

Characteristics	Grade A	Grade B
Fruits		
Fruit	12.1 ± 0.4	11.8 ± 0.4
Colour		
Red	0.0	1.7
Yellow	48.0	35.0
Blue	3.2	0.0
Visual density	0.510	0.290
X	0.412	0.484
Y	0.558	0.496
Z	0.030	0.020
Brightness (%)	30.9	51.2
Dominant hue	567	57.7
Wavelength (nm)		
Saturation (%)	56.6	90.9
Fruit dimensions (cm)	6.5×5.2	7.5×6.0
Fruit weight (g)	82.6 ± 2.2	84.8 ± 2.5
Juices		
Yield (%)	55.6 ± 1.0	59.4 ± 1.1
Specific gravity (gm ml^{-1})	1.032 ± 0.001	1.034 ± 0.001
Colour		
Red	0.2	0.6
Yellow	35	35
Blue	0.2	–
Visual density	0.21	0.23
X	0.438	0.454
Y	0.532	0.521
Z	0.030	0.025
Brightness (%)	61.6	58.8
Dominant He wavelength	570	573
Saturation (%)	93.2	95.6

Table 2
Some chemical constituents of Bearss Seedless lime juices

Constituents	Grade A	Grade B
Dry matter (%)	9.84b	9.82a
Protein (%)	0.365b	0.380a
Ash (%)	0.322b	0.329a
Na (mg/100 g)	1.95a	1.90a
K (mg/100 g)	78.1b	82.4a
Ca (mg/100 mg)	6.50a	6.63a
Fe (mg/100 mg)	0.51a	0.53a
P (mg/100 mg)	8.54b	8.66a

Table 3
Amino acid composition of Bearss Seedless lime juices (mg/100 g)

Amino acid	Grade A	Grade B
Arginine	27.2	23.4
Lysine	6.3	5.7
Histidine	4.4	6.0
Phenylalanine	3.2	3.0
Tyrosine	2.1	2.3
Leucine	0.6	0.6
Isoleucine	0.7	0.5
Methionine	0.3	0.3
Valine	1.9	1.6
Alanine	6.8	7.8
Glycine	1.7	1.7
Proline	12.4	14.1
Glutamic acid	20.2	23.0
Serine	8.7	7.9
Threonine	1.7	1.5
Aspartic acid	28.7	25.0

Opposite to the pH values, the titratable acidity was found to increase gradually as storage period was elongated and the increases were markedly higher for refrigerated juices than their frozen counterparts. The total acidity was much higher for B juice than A (Table 4).

A gradual decrease was traced for ascorbic acid content of lime juice stored in the refrigerator (declines of 13.9 and 13.6% for A and B grades, respectively). Freezing did not appreciably affect titratable acidity or ascorbic acid (Table 4).

Table 5 reveals that Brix° were markedly higher for lime juice belonging to grade B than from fruits of grade A. No noticeable changes were detected in Brix° for samples under frozen storage.

Reducing sugars of lime juice were found to increase on storage. Such increase was much more pronounced for refrigerated samples (Table 5). In contrast, the total sugars contents were found to decrease under the aforementioned conditions (Table 5).

Table 6 gives percentages of reducing sugars, total sugars and titratable acidity (as percentage of Brix°) for lime juices stored in glass bottles under refrigeration and freezing conditions. As can be seen, reducing sugars/Brix° and titratable acidity/Brix° increased as the storage proceeded. This was true for both refrigeration

Table 4
The pH, titratable acidity and ascorbic acid content of stored Bearss Seedless lime juice

	Grade A						Grade B					
	PH		Tiratable acidity (%)		Ascorbic acid (mg/100 ml)		PH		Tiratable acidity (%)		Ascorbic acid (mg/100 ml)	
Weeks	R[a]	F[a]	R	F	R	F	R	F	R	F	R	F
0	2.62	2.62	6.33	6.33	36.1	36.1	2.42	2.42	6.86	6.86	33.8	33.8
3	2.60	2.62	6.36	6.34	35.8	36.0	2.40	2.42	6.87	6.84	33.5	33.7
6	2.59	2.61	6.38	6.34	35.6	36.0	2.40	2.41	6.88	6.84	33.4	33.6
9	2.57	2.60	6.32	6.35	35.0	35.8	2.38	2.40	6.92	6.85	33.0	31.4
12	2.56	2.60	6.35	6.36	34.7	35.7	2.37	2.41	6.95	6.86	32.7	33.4
15	2.54	2.60	6.37	6.36	34.5	35.7	2.34	2.40	6.97	6.86	32.5	33.3
18	2.53	2.59	6.43	6.36	3.41	35.8	2.30	2.40	7.82	6.86	32.3	33.3
21	2.50	2.58	6.47	6.37	33.8	35.6	2.30	2.39	7.07	6.87	31.4	33.2
24	2.48	2.58	6.50	6.38	33.2	35.7	2.26	2.39	7.12	6.88	31.0	33.1
27	2.46	2.58	6.58	6.38	32.9	35.6	2.24	2.32	7.12	6.88	30.2	33.6
30	2.43	2.59	6.57	6.40	31.1	35.6	2.21	2.38	7.17	6.98	29.2	32.8

[a] R, refrigerated sample (5 ± 1°C); F, frozen sample (−20 ± 1°C).

Table 5
Brix° reducing sugars and total sugars contents of Bearss Seedless lime juice during storage

	Treatment											
	Grade A						Grade B					
	R[a]			F[a]			R			F		
Weeks	Brix°	R. sugar[b]	T. sugar[b]	Brix°	R. sugar	T. sugar	Brix°	R. sugar	T. sugar	Brix°	R. sugar	T. sugar
0	9.48	0.58	0.78	9.48	0.58	0.78	0.82	0.59	0.86	9.82	0.59	0.76
3	9.46	0.60	0.78	9.45	0.58	0.78	9.82	0.61	0.86	9.80	0.59	0.76
6	9.48	0.61	0.76	9.45	0.59	0.76	9.80	0.63	0.85	9.82	0.69	1.75
9	9.47	0.60	0.77	9.48	0.58	0.78	9.80	0.64	2.84	9.82	0.59	0.76
12	9.48	0.62	0.74	9.45	0.58	0.76	9.82	0.64	0.84	9.83	0.60	0.75
15	9.45	0.61	0.74	9.45	0.60	0.77	9.80	0.65	0.85	9.81	0.60	0.76
18	9.47	0.61	0.72	9.48	0.59	0.76	9.82	0.68	0.84	0.80	0.59	0.75
21	9.46	0.62	0.70	9.43	0.60	0.76	9.82	0.68	0.84	0.80	0.61	0.75
24	9.48	0.64	0.70	9.45	0.61	0.76	9.80	0.69	0.83	9.82	0.60	0.75
27	9.45	0.63	0.70	9.45	0.62	0.74	9.80	0.71	0.83	9.89	0.60	0.75
30	9.8	0.64	0.68	9.46	0.62	0.74	9.8C	0.73	0.82	0.80	0.60	0.74

[a] R, refrigerated juice, F, frozen juice.
[b] R, sugar, reducing sugars; T, sugar, total sugars.

Table 6
Reducing sugars, total sugars and titratable acidity as percentages of the Brix° for Bearss Seedless lime juice during storage

	Grade A						Grade B					
	Refigeration			Freezing			Refrigeration			Freezing		
Weeks	R. sugar[a]	T. sugar[a]	TA	R. sugar	T. sugar	TA	R. sugar	T. sugar	TA	R. sugar	T. sugar	TA
0	6.12	8.23	66.8	6.12	8.22	66.8	6.01	8.76	69.9	6.01	7.74	69.9
3	6.34	8.25	67.1	6.14	8.25	67.1	6.21	8.76	70.0	6.02	7.76	69.8
6	6.43	8.02	67.3	6.24	8.04	67.1	6.43	8.67	70.2	6.11	7.74	69.7
9	6.33	8.13	66.7	6.13	8.22	67.0	6.53	8.57	70.6	6.01	7.74	69.8
12	6.54	7.81	67.0	6.14	8.04	67.3	6.52	8.55	70.8	6.10	7.63	69.8
15	6.46	7.83	67.4	6.35	8.15	67.3	6.63	8.67	71.1	6.12	7.75	69.9
18	6.45	7.60	67.9	6.22	8.02	67.1	6.92	8.55	71.6	6.02	7.65	70.0
21	6.55	7.39	68.4	6.35	8.06	67.6	6.92	8.55	72.0	6.22	7.65	70.1
24	6.75	7.38	68.6	6.46	8.04	67.5	7.04	8.47	72.5	6.11	7.64	70.1
27	6.67	7.41	69.6	6.56	7.83	67.5	7.24	8.47	73.3	6.22	7.65	70.2
30	6.75	7.17	69.3	6.55	7.82	67.7	7.45	8.37	73.2	6.12	7.55	70.4

[a] R. Sugar, reducing sugars, T. sugar, total sugars; TA, titratable acidity.

Table 7
Browning index and AE of Bearss Seedless lime juice during storage

	Grade A				Grade B			
	Browning index[a]		ΔE^b(cm)		Browning index[a]		ΔE^b (cm)	
Week	R[c]	F[c]	R	F	R	F	R	F
0	0.155	0.155	0.0	0.0	0.163	0.163	0.0	0.0
3	0.161	0.157	0.3	0.2	0.171	0.167	0.2	0.1
6	0.168	0.160	0.5	0.2	0.177	0.172	0.3	0.2
9	0.177	0.162	0.6	0.3	0.187	0.177	0.5	0.2
12	0.189	0.163	0.6	0.5	0.195	0.178	0.6	0.3
15	0.196	0.167	0.8	0.5	0.203	0.182	0.8	0.4
18	0.205	0.169	0.7	0.6	0.210	0.187	0.8	0.4
21	0.211	0.173	0.9	0.7	0.218	0.190	0.9	0.5
24	0.220	0.178	1.0	0.6	0.222	0.190	0.1	0.6
27	0.231	0.182	1.1	0.7	0.230	0.190	0.1	0.6
30	0.240	0.184	1.1	0.7	0.234	0.192	0.2	0.7

[a] Browning index = A° at 420 nm.
[b] ΔE, the distance between actual point at given time and the point at zero time on CIE chromaticity diagram (cm).
[c] R, refrigerated juice; F, frozen juice.

and frozen storage with the former being higher than the latter. In contrast, total sugars/Brix° decreased with elongation of storage. The points of interest are that the rates of change were much more pronounced for refrigeration than freezing and for juice extracted from grade A fruits than counterparts extracted from grade B ones.

Data for browning index and ΔE (the distance between the point of fresh juice colour at zero time on CIE chromaticity diagram and the point for the same sample at a given time of storage by cm) are shown in Table 7. The browning index for fresh B juice was slightly higher than A. Due to the gradual increase in reducing sugars and the presence of free amino acids, the browning index increased gradually during storage. The values increased by about 55 and 15% for A and about 44 and 13% for B, as affected by storage for 30 weeks, at 5 ± 1°C and -20 ± 1°C, respectively. The ΔE value, as related directly to the browning index, showed the same trend.

Sensory evaluation of stored juices revealed that frozen juices were accepted up to the end of the experiment (30 weeks). Notwithstanding, samples stored at 5°C deteriorated markedly and were not acceptable after 27 and 21 weeks of storage of A and B juices, respectively. The rejection of samples was mainly related to the bitterness and sourness rather to the colour of juice (Table 8).

Table 8
Sensory evaluation of Bearss Seedless lime juice during storage

	Grade A								Grade B							
	Bitterness		Sourness		Colour[a]		Overall aceptability		Bitterness		Sourness		Colour		Overall aceptability	
Weeks	R[b]	F[b]	R	F	R	F	R	F	R	F	R	F	F	F	R	F
0	8.7	8.7	9.0	9.0	9.0	9.0	8.8	8.8	8.9	8.9	8.8	8.8	9.0	9.0	8.8	8.8
3	8.0	8.4	8.2	9.0	8.8	8.7	8.2	8.4	8.0	8.6	8.1	8.9	8.3	8.7	8.1	8.4
6	7.5	8.5	7.5	8.7	8.5	8.8	7.9	8.6	7.7	8.8	7.5	8.4	8.0	8.7	7.8	8.3
9	7.1	7.9	7.1	8.3	8.0	8.3	7.4	8.3	7.0	8.3	7.1	8.6	7.8	8.4	7.5	8.1
12	7.2	8.2	6.6	8.4	7.9	8.4	7.5	8.1	6.6	8.4	6.4	8.1	7.8	8.1	6.8	7.7
15	6.7	7.7	6.8	8.0	7.7	8.2	7.0	7.9	6.7	7.9	6.5	8.2	7.5	8.0	6.3	7.8
18	6.2	7.8	6.0	7.7	7.0	7.9	6.3	8.1	6.1	8.0	6.0	7.6	7.1	7.6	6.1	7.5
21	5.5	7.7	5.7	7.8	7.1	8.0	6.3	7.7	5.7	7.5	5.5	7.7	7.0	7.7	5.7	7.7
24	5.1	7.5	5.2	7.3	6.8	7.5	5.7	7.2	4.9	7.7	5.0	7.3	6.8	7.2	4.9	7.5
27	5.0	7.6	5.2	7.0	6.3	7.7	5.2	7.4	4.9	7.5	4.7	7.0	6.3	7.3	4.7	7.0
30	4.4	7.7	4.5	7.2	6.3	7.2	4.3	7.1	4.3	7.0	4.5	7.1	6.4	6.9	3.8	7.0

[a] Mean of 10 panelists' score (CV did not exceed 5%).
[b] R, refrigerated juice; F, frozen juice.

References

Ali, E. A. S. (1996). *Chemical and technological studies on packaging materials as factors affecting quality of some processed vegetables and fruits*. MSc thesis, Alexandria University Alexandria, Egypt.

AOAC (1990). *Official methods of analysis* (Vol. II) (15 th ed.). Arlington, VA: Association of Official Anaytical Chemists.

Carter, B. A. (1990). Lemon and lime juices. In S. Nagy, C. S. Chen, & P. E. Shaw, *Fruit juice processing technology*. Auburndale, FL: AgScience.

Curl, A. L., & Talburt, W. F. (1961). Deterioration in storage. In D. K. Tressler, & M. A. Joslyn, *Fruit and vegetable juice processing technology* (p. 410). West Port, CT: AVI Pub. Co.

De Man, J. M. (1990). *Principles of food chemistry* (2nd ed.). WestPort CT: AVI Pub. Co.

Egan, H., Kird, S. R., & Sawyer, R. (1981). *Pearson's chemical analysis of foods*. Churchill Livingstone. Melbourne, New York: Edinburgh, London.

El-Helaly, A. A. (1995). *Effect of some postharvest treatments on keeping quality and storage period of Banzahir and Housseni Lime Fruits during Cold Storage*. PhD thesis, Alexandria University, Alexandria, Egypt.

Fernandez-Flores, E., Kline, D. A., & Johnson, A. R. (1970). Quantitative GLC analysis of free amino acids in fruits and fruit juices. *Journal of the Association of Official Analalytical Chemists, 53*, 1203.

Groch W., & Schieberle, P. (1987). Identification of flavour compounds formed during deterioration of lemon oil. In Martens, M., & H. Russwurm Jr., G. H. *Flavour science & technology* (p. 119). John Wiley & Sons Ltd.

Harding, P. K., Winston, J. B., & Fisher, D. F. (1940). Seasonal changes in Florida oranges. *US Department of Agricuture Technical Bulletin, 753*, 1–89.

Kacem, B., Cornell, J. A., Marshall, M. R., Shireman, R. B., & Matthews, R. F. (1987). Nonenzymatic browning in aseptically packaged orange drinks: Effect of ascorbic acid, amino acids and oxygen. *Journal of Food Science, 52*, 1668.

Kacem, B., Matthews, R. F., Crandall, P. G., & Cornell, J. A. (1987). Nonenzymatic browning in aseptically packaged orange juice and drinks: Effect of amino acid, deareation and anaerobic storage. *Journal of Food Science, 52*, 1665.

Kimura, K., Nishimura, H., Iwata, I., & Mizutani, J. (1983). Ceterioration mechanism of lemon flavor: 2 — Formation mechanism of off-odour substances arising from citral. *Journal of Agricultural and Food Chemistry, 31*.

Meydav, S., Saguy, I., & Kopelman, J. I. (1977). Browning determination in products. *Journal of Agricultural and Food Chemistry, 25*, 602.

Nagy, S., & Rouseff, R. L. (1980). Evaluation and control of undesirable flavours in processed citrus juices. In G. Charalambous, *The analysis and control of less desirable flavours in foods and beverages* (p. 171). New York: Academic Press, Inc.

Robertson, G. L., & Samaniego, C. M. L. (1986). Effect of initial dissolved oxygen levels on the degradation of ascorbic acid and the browning of lemon juice during storage. *Journal of Food Science, 51*, 184.

Shaw, P. E. (1996). Volatile components important to citrus flavors. In J. A. Redd, *et al.*, *Quality control manual for citrus processing plants*. (Vol. III). Auburndale, FL: AgScience.

Simmonds, D. C. (1984). Fruit juices and soft drinks. In Food industries manual. (21st ed). M. D. Ranken. (p. 228). Blackie & Sons Ltd.

Southgate, D. A. T. (1976). *Selected methods in determination of food carbohydrates*. London, England: Applied Science Pub. Ltd.

Swisher, H. E., & Swisher, L. H. (1980). Lemon and lime Juices. In D. K. Tressler, & M. A. Joslyn, *Fruit and Vegetable Juice processing Technology* (3rd ed) (p. 125). West-Port. CT: AVI Pub. Co.

Ziena, H. M. S., Youssef, M. M., & Aman, M. E. (1997). Quality attributes of black olives as affected by different darkening methods. *Food Chemistry, 60*, 501.