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Quality Control of Lime Juices from Iran

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Lime samples from three major lime-producing locations of Iran were investigated for their quality control (total acidity, total soluble solid, total solid content, pH, ash content, alkalinity of ash and formol titration). Total soluble solid was significantly higher in limes from Jahrom than those from Roudan and Minab. Similarly, the average value of vitamin C content in limes obtained from Jahrom (37.9 ± 2.7 mg/100 mL,) was significantly higher than those of Roudan (34.2 ± 2.2) and Minab (35.3 ± 2.2). Other parameters also showed some differences. But, despite such differences, the ratios of total soluble solid to total acidity, so-called "maturity ratio," for the limes from the three regions were similar indicating that they had similar palatability levels.

Key Words: Ascorbic acid, Citric acid, Maturity ratio, Lime, Total acid.

INTRODUCTION

The citrus industry in Iran is mainly focused on lime (*Citrus aurantifolia Swingle*) production for juice processing. Jahrom (Fars, Iran), Roudan (Hormozgan, Iran) and Minab (Hormozgan, Iran) are major regions producing this fruit. According to the reports[1], the lime has originated from East Indian archipelago. Other than the taste that citrus fruits are importing into the products they are used with these fruits also render certain health benefits[2]. Among the neutraceuticals, vitamin C and a phenolic compound have been reported in lemon juice, a close family of lime. Zulueta *et al.*[3] reported that the main contribution to the total antioxidant capacity was from the vitamin C part of the fruit juice. Also, there are other compounds such as water, citric acid, amino acids, ascorbic acid and minerals, which are highly important in identifying a cultivar and also for identifying the cultivation area. However, no such studies were found in the literature to report on these aspects of the limes, especially those grown in Iran. Therefore, the objective of this study was to investigate on quality attributes of limes grown in Jahrom, Roudan and Minab, which are major cities for the production of this cultivar in Iran.

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EXPERIMENTAL

The limes from the three lime-growing regions (Jahrom, Roudan and Minab) were brought to the lime beverage factory during summer through fall of 2006. As soon as samples arrived, a few kg of mature, medium-size limes with an average fruit weight of about 30 g were separated and taken to the laboratory. The diseased, bruised and injured limes were then discarded and limes with uniform size and appearance were randomly distributed into different lots. The limes were then cut and placed in a hand press where juices were extracted. The extracted juices were then filtered to remove all solid particles. One litre juice was collected for each sample. 30 Different samples of lime were examined for each region. Samples were measured for their chemical properties (total acidity, total soluble solid, total solid content, pH, ash content; alkalinity of ash, formol titration, vitamin C content) at the same time. All chemicals were of analytical grade (Merck Chemical Company, Darmstadt, Germany) and used were without further purification.

Total acidity as citric acid content was determined by direct titration of 1.0 mL of lime juice with sodium hydroxide (0.1 N) using phenolphthalein as indicator[4]. Total soluble solid (°Brix) was assessed from the refractive index of a drop of sample at 20 °C using a refractometer (model Atago Pal-3, Tokyo, Japan). Total solid content was determined by pipetting 10.0 mL of each sample into a pre-dried aluminum plate, which was then allowed to dry at 100 ºC . The pH values were measured using a pH meter. The ash content was obtained by igniting the samples at 550 °C after a preliminary evaporation on a gentle boiling water bath. Alkalinity of the ash (reported as g potassium carbonate) was determined by gently boiling the ashed samples with known amounts of hydrochloric acid (0.1 N) followed by cooling and back-titrating with sodium hydroxide (0.1 N) using methyl orange as indicator (1 mL (0.1 N) NaOH is equivalent to 6.9 mg potassium carbonate). Formol titration was determined by concentrating 200 mL of juice in a porcelain dish on a water bath at 80 °C for 2 h followed by cooling and back-titrating to pH 8.0 using NaOH (1.0 N). Fine adjustment of pH was carried out using 0.1 N NaOH towards the end of the neutralization process. 20 mL of 35 % formaldehyde (formalin, previously neutralized to pH 8.0) was added prior to the back-titration step. To determine formaldehyde number, total amount of NaOH consumed in this procedure was divided by 2. Vitamin C content was determined by pipetting 50.0 mL of the sample into a 100.0 mL volumetric flask, adding 25 mL of 20 % (w/w) metaphosphoric acid as stabilizing agent and making it up to the mark with water. 10 mL of the solution was then pipetted into a small flask and after adding 2.5 mL acetone, it was titrated with the indophenol solution until a faint pink colour was persistent for 15 s. Vitamin C content was reported as mg ascorbic acid per 100 mL of the sample juice[5].

Statistical analysis: The statistical analysis of the data was carried out using the GLM procedure from SAS (Statistical Analysis Software, version 9.1, SAS Institute Inc., Cary, NC, USA). Means of triplicate analysis from 30 samples of each region were reported for the parameters studied.

RESULTS AND DISCUSSION

Several analytical properties of the studied limes are given in Tables 1 and 2. Total acidity was higher in limes obtained from Jahrom but those from Roudan and Minab did not differ from each other. Means of acidity among all the samples from the three regions varied from 5.5 to 7.2 g/100 g of the sample (Table-3). da Conceicao Neta *et al.*[6] reported that sour taste intensity was linearly related to the sum of hydrogen ion concentration and those of organic acid species such as citric acid and anionic citrate. Therefore, it can be concluded that lime juices from Jahrom with an acidity value of 6.59 (compared to 6.01 for juices from Roudan and 5.86 from those of Minab, respectively) and a pH level similar to those of Minab and Roudan have higher sourness level than those of the other two lime juices. Xu *et al.*[2] reported a total acidity value of 6.1 g/100 g for lemon, which is very close to the value obtained in this study.

TABLE-1
TOTAL ACIDITY (TA, g/100 g SAMPLE), TOTAL SOLUBLE SOLID (TSS, g/100 g SAMPLE) AND pH OF LIME JUICES HARVESTED FROM JAHROM, ROUDAN AND MINAB (IRAN) IN 2006

Analytical property	Jahrom*	Roudan*	Minab*
Total acidity (TA)	6.59 ± 0.31^{a}	6.01 ± 0.28^{b}	5.86 ± 0.23^{c}
TSS	8.73 ± 0.34^{a}	7.98 ± 0.16^{b}	7.92 ± 0.20^{b}
pH	2.48 ± 0.08^{b}	2.47 ± 0.07^{b}	2.59 ± 0.10^{a}
TSS/TA**	1.33 ± 0.06^{a}	1.33 ± 0.07^{a}	1.36 ± 0.07^{a}

*Mean ± SD (n = 30). In each row, means with the same letter are not significantly different ($p < 0.05$).
**TSS/TA: the ratio of total soluble solid to total acid.

Jahrom located at 53.38°E and 28.50°N with an altitude of 1050 meter above the sea level has a cooler climate compared to Roudan and Minab, which are located at different geographical positions (Table-4) and as a result it has a warmer climate. Davies and Albrigo[1] reported that the rate of decrease in the acidity was positively correlated with the average temperature during each season. Furthermore, it was shown that the respiration rates

TABLE-2
SEVERAL ANALYTICAL PROPERTIES OF LIME JUICES HARVESTED FROM THREE DIFFERENT LOCATIONS OF IRAN (JAHROM, ROUDAN AND MINAB) IN 2006

Analytical property	Jahrom*	Roudan*	Minab*
Total solid (g/100 g sample)	9.13 ± 0.47[a]	8.93 ± 0.28[b]	8.81 ± 0.19[b]
Total ash (g/100 g sample)	0.46 ± 0.03[a]	0.41 ± 0.02[b]	0.38 ± 0.02[c]
Alkalinity of soluble ash (g/100 g sample)	0.24 ± 0.03[a]	0.25 ± 0.02[a]	0.23 ± 0.03[a]
Formol titration (mL/100 g sample)	27.45 ± 1.72[a]	26.35 ± 1.34[b]	25.51 ± 1.39[c]
Vitamin C concentration (mg/100 g sample)	37.90 ± 2.70[a]	34.20 ± 2.20[b]	35.30 ± 2.20[b]

*Mean ± SD (n = 30). In each row, means with the same letter are not significantly different ($p > 0.05$).

TABLE-3
OVERALL MEANS OF CHEMICAL COMPOSITIONS OF THE LIME JUICES HARVESTED FROM THE THREE DIFFERENT LOCATIONS OF IRAN IN 2006

Analytical properties	Variation limits*			
	Min	Max	Mean	SD
Total acidity (g/100 g sample)	5.50	7.20	6.10	0.40
Total soluble solid (g/100 g sample)	7.50	9.50	8.20	0.40
pH	2.33	2.80	2.52	0.10
Total solid (g/100 g sample)	8.40	10.00	8.90	0.30
Total ash (g/100 g sample)	0.35	0.50	0.42	0.04
Alkalinity of ash (g/100 g sample)	0.20	0.30	0.25	0.02
Formol titration (mL/100 g sample)	22.50	29.50	26.40	1.70
Vitamin C Content (g/100 g sample)	30.00	42.00	35.80	2.80
TSS:TA**	1.18	1.53	1.34	0.07

*n = 90; **TSS:TA = The ratio of total soluble solid to total acid.

TABLE-4
GEOGRAPHICAL SITUATION OF THREE DIFFERENT LOCATIONS OF IRAN (JAHROM, ROUDAN AND MINAB)

City	Altitude	Longitude	Latitude
Jahrom	1050	53.38	28.50
Roudan	40	57.60	27.15
Minab	179	57.20	27.92

are increased at higher temperatures[1] possibly causing less storage of acids in the vacuoles and their faster utilization in plant metabolisms. Therefore, acidity contents were grater in the limes obtained from Jahrom due to its milder conditions compared to Minab and Roudan. On the other hand, total acidity of citrus fruits is an important factor in evaluating the overall juice quality and in determining harvest time[7]. In the current study, limes were harvested when they were fully mature (*i.e.*, at their best harvest times). Therefore, the optimum acidities for fruit pick-up were 6.59 g/100 g sample for Jahrom, 6.01 g/100 g sample for Roudan and 5.86 g/100 g sample for Minab.

Total soluble solid was significantly greater in limes obtained from Jahrom than those obtained from Roudan and Minab. Mean values for total soluble solid from the three regions varied from 7.5 to 9.5 g/100 of samples (Table-3). For juice producing factories, higher total soluble solid represents a better quality of lime juice, which in turn results in juices with higher consumer acceptance levels. Obviously, the future standard levels of total soluble solid mandated by any standard agency in Iran needs to consider such variation for defining the minimum total soluble solid for lime-juice producing plants. Total soluble solid value of 10.9 g/100 g of sample was reported for lemon by Xu *et al.*[2]. Although TSS values from this study are fairly close to that reported by Xu *et al.*[2], the small differences can be mainly attributed to the differences in the type of the fruit (*i.e.*, the variety). Despite such differences, the TSS/TA ratios, so-called maturity ratios, for the limes obtained from the three regions studied here were similar (Table-1) indicating that they had similar palatability levels. This ratio increases as the fruit ripens[5]. According to the reports by Fellers *et al.*[8] about the influence of this ratio on the consumer acceptance of the processed grapefruit juice, consumer perception of sweetness increased and instead some factors such as tartness, bitterness and aroma decreased with an increase in this ratio. These findings show that maturity ratio is important factor to determine the best pick-up time of the fruit for the optimum flavour content. In the current study, fully matured limes were used and therefore, it can be concluded that the best time of harvesting of lime is when the maturity ratio is at 1.34 ± 0.07 level (Table-3). A maturity ratio of 1.8 has been reported for lemon juices obtained from China by Xu *et al.*[2] indicating such values can vary with variety of citrus fruit. The pH values for the juices obtained from Minab were significantly greater than those of Jahrom and Roudan (Table-1). Also, as expected, with an increase in acidity, the pH values decreased among the juices studied here.

Other analytical parameters including total solid, ash content, alkalinity of ash, formol titration values and vitamin C contents of the limes among the juices studied are presented in Table-2. Other than alkalinity of soluble

ash, which was not different among all the locations, other parameters were greater in juices from Jahrom than those from Roudan and Minab. Furthermore, total ash and formol titration were significantly greater in juices from Roudan than those from Minab. The average value of vitamin C content in limes obtained from Jahrom was 37.9 ± 2.7 mg/100 mL of the juice, which was significantly higher than those of Roudan (34.2 ± 2.2 mg/100 mL) and Minab (35.3 ± 2.2 mg/100 mL). According to these results, limes studied here have greater vitamin C contents than those reported by Pearson[5] (25.0 mg/100 mL) for juices obtained from several different sources. Vitamin C functions as a coenzyme and it is an essential part of human diet[9]. High levels of this nutrient in limes grown in Iran (Table-3) with a mean value of 35.8 ± 2.8 suggest more investigation on the limes grown in this area.

Based on the results of this study, maturity ratios (1.33-1.36) for the limes harvested from the three regions were similar indicating similar quality attributes among them. Chemical compositions of the limes obtained from the three regions, which are considered major regions for the production of this cultivar in Iran (Table-3), can suggest the standard acceptable levels of juices offered in the market.

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