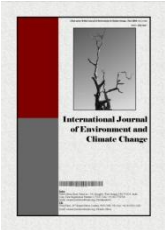

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Physico-chemical Changes in Assam Lemon (*Citrus Limon* Burm.) during Fruit Development and Maturation

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Studies were conducted on the physico-chemical changes associated with fruit development in Assam lemon. Fruit growth was slow initially upto 95 days after fruit set (DAFS) and it increased rapidly in terms of fruit weight and size of the fruit, from 45.54g & 75.75 cm^2 until maturity. The trend in specific gravity of the fruits increased with fruit development and reached the value to 2.7 at harvest maturity. Therefore specific gravity of the fruit could be considered as a reliable physical index for harvest maturity. During early stage of fruit growth the juice content percentage was found low which increased as fruit growth advanced towards maturity. Total soluble solids (TSS) to acidity ratio showed an increased trend during fruit development in Assam lemon. At maturity TSS to acidity ratio reached values between 1.99 to 2.81^{0}Brix. TSS to acidity ratio could also be considered as the reliable chemical index for harvest maturity. Bio chemical characteristics such as Ascorbic acid and Pectin content also showed an increasing trend with fruit development and maturity. However the chlorophyll content showed a down ward trend and at harvest maturity it recorded 0.185mg/g. Results indicated that Assam lemon attained full maturity at 135-140 days and harvest maturity in 130 days after fruit set.

Keywords: Harvest maturity; optimum stage; TSS: acid ratio; ascorbic acid.

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1. INTRODUCTION

Citrus occupies a place of considerable importance in the fruit economy of the country. The most important citrus fruits grown in the North East India on commercial scale are the mandarins and lemons. Assam lemon or Citrus limon are important cultivars of lemon in India originating in Southeast Asia, China, and the Malayan Archipelago. It bears fruits almost throughout the year and is the main source of vitamin C in the diet of common masses [1]. Aside from being rich in vitamin C, and assists in warding off infections, the juice is traditionally used to treat scurvy, sore throats, fevers, rheumatism, high blood pressure, and chest pain. It also used for culinary purposes and preparation of beverages as refreshing drink.

Although considerable amount of work has been done on growth and development of commercially important fruits of citrus in India, such as oranges, mandarins, pummelos. However literature on physico chemical changes associated with the fruit growth and maturation in Assam lemon is rather scanty. Bharali & Saikia [2] studied a few aspects of physico-chemical changes associated with growth and development of pummelo (Rabab tenga, white flesh, citrus grandis L) fruits. Detailed information regarding study on physico-chemical changes associated with fruit growth and development during maturation would be useful to determine the optimum stage of maturity to harvest Assam lemons [3-5]. Therefore, the present investigation was undertaken to study various physico- chemical changes including pectin during fruit growth and maturation to determine the optimum stage of fruit maturity for harvest.

2. MATERIALS AND METHODS

Twenty four(24) healthy Assam lemon trees of equal age (18 years old) were distributed in the randomized block design with three replications of eight (8) trees, which were selected from an orchard in Jorhat,(Lat:26.7445 & Lng:4.22394),Assam. Forty developing fruits were tagged from each tree at 10 days after fruit set. Thirty tagged fruits of lemons were picked from three replicates. The stages of fruit harvest included from 90 DAFS at 5 days interval upto 140 DAFS. The harvested fruits were used for determining the physico –chemical changes.

2.1 Physical Characteristics

At each stage, fruits were harvested with stalk, then destalked and fruit weight was recorded. Physical parameters of the fruit were taken in terms of size of the fruit (cm^2), rind thickness (mm), length from pith to albedo (cm), fruit weight (g), specific gravity, juice content (%), pedicel colour (visual) and peel colour. Size of the fruit, rind thickness and length from pith to albedo were measured with digital vernier calliper, fruit weight with electronic balance, and specific gravity as weight per unit volume of the fruits by water displacement method (w/v) Shivasankar and Kumar, (1999). The juice was measured with the help of graduated cylinder and then expressed into percentage.

The fruit quality parameters were studied in terms of total soluble solids (^{0}Brix), titratable acidity (%), ascorbic acid (mg/100g) and TSS:acid ratio. Total soluble solid (TSS) was determined with the help of digital refractometer. Acidity and ascorbic acid content of the fruit were estimated following the standard procedures described by AOAC [6]. The total chlorophyll in the peel portion of the fruit samples was estimated according to the method described by Ranganna [7]. The pulp of the fruits (5fruits) at each stage was macerated in a blender and it was used for chemical analysis. Pectin content from the citrus peel was extracted as per the procedure described by Ranganna [7].

3. RESULTS AND DISCUSSION

3.1 Physical Characteristics

The fruit growth in terms of fruit size, weight and length from pith to albedo of Assam lemon fruits increased till fruit maturity (Table1). However increase in fruit size and weight was more rapid from 90 DAFS (75.75 cm^2), (45.54g) upto 125 DAFS (120.70cm^2), (125.40g) respectively. Similarly the length from pith to albedo was also observed to increase rapidly from 90 DAFS to 125 DAFS after which the changes was found to be non-significant. This increase in fruit size, weight and length from pith to albedo can be attributed to cell enlargement Choudhury [8]. The increase might also be due to the fact that developing fruit acts as a strong physiological ‘sink’ attracting nutrients to its tissue. Therefore there will be an enhanced deposition of metabolites inside the cells. On the contrary the rind thickness decreased with fruit maturity and

development. Similar results were also observed by Deka et al.[9] in Khasi mandarin.

The specific gravity of lemon fruit increased from 1.20 to 2.75 (from 100 to 130 DAFS) due to an increase in the juice content and SSC (soluble solid content) of the juice. Similar results were reported in pummelo by Bharali & Saikia [2].

The juice percentage increased as maturity progressed, and 38.12% of the juice was recovered at 140 DAFS of Assam lemon. The increase in juice content might be accounted for the accumulation of water and solutes to the juice vesicles and a decrease in the percentage of rind weight This is in accordance to the finding of Dharbale et al [10] in sweet orange.

Changes in total chlorophyll and pedicel colour of Assam lemon fruits during fruit development, in the present study, showed that the chlorophyll in the rind portion of the fruits increased from 90 DAFS till 105 DAFS (from 0.271 to 0.282 mg/g) and then declined upto fruit maturity and ripeness *ie* 140 DAFS . The decrease content of chlorophyll content may be due to the increased carotenoid pigments, Kardile et al [10].Similar results were also observed by kumar et.al [12] in acid lime.

With maturity and ripeness of the lemon fruits it was observed that the pedicel colour changed towards lighter green from dark green colour (Table 1.)

3.2 Chemical Composition

As evident from Table 2, the TSS content in the fruit juice of Assam lemon increased progressively and appreciably with the advancement of fruit maturity and attained a peak at 115 DAFS (6.5^0Brix) and then it was found to decline. The increase in TSS could be due to higher sugar content, which may be attributed to conversion of complex carbohydrates into simple sugars. Similar results were found by Sema and Sanyal [13] in Assam lemon.

The decline of TSS after 115 DAFS could be attributed to the utilization of sugar as a substrate for increased rate of respiration during storage. This is also in accordance with the findings of Barua [14] in *khasi* mandarin.

An increase acidity content was noticed from 90 to 125 DAFS (1.54 to 3.41%) and then there was a fall upto 140 DAFS. Increase in citric acid during fruit development might be due to higher synthesis of acid in juice vesicles by enzymatic action [15]. Similar finding was also reported by Ladaniya and Singh [16] in Kagzi lime. Again the decrease in acidity content might be due to conversion of acids into salts and sugars by enzymes such as polygalacturonase, pectin methyl esterase and lyase. The decrease in acidity could also be attributed to dilution of acid with increase in juice content with maturity. Similar observations were recorded by Harding and Sunday, [3] in citrus fruits.

Sugar acid ratio is an essential factor in determining the quality of fruits. Sugar acid ratio was found to decrease with advancement of maturity of Assam lemon fruits. Increase in acidity content with maturity of fruits might be the reason behind decrease in sugar acid ratio [17-19].

In the present study, it was observed that the ascorbic acid content of lemon fruits increased upto 120 DAFS (69.92 mg/100g) and then showed decline uptill 140 DAFS (40.20 mg/100g). The fall in ascorbic acid content might be due to the accelerated maturity during these stages and utilization in certain metabolic processes such as increased rate in respiration, increase in ethylene production [20,21], fruit acidity changes and changes in starch and sugar content. Similar results were observed by Sema and Sanyal [13] in Assam lemon.

The Pectin content was found to increase initially during fruit growth and development of lemon fruits (3.38%) upto 120 DAFS and then declined upt0 140 DAFS (3.20%) which was non-significant. Increase in pectin is due to the known reason that during fruit development the non soluble protopectin is converted to water soluble pectin.

Table 1. Physical characteristics of Assam lemon at different stages of maturity

Days after fruit set (DAFS)	Weight of fruit (g)	Size of fruit (cm^2)	Rind thickness (mm)	Length from pith to albedo (cm)	Specific gravity	Juice content (%)	Chlorophyll content (mg/g)	Pedicel colour (Visual)
90	45.54	75.75	7.0	1.40	1.20	20.12	0.271	Dark green
95	52.06	78.02	6.0	1.40	1.20	22.0	0.270	Dark green
100	64.82	81.00	6.0	1.40	1.20	24.04	0.282	Dark green
105	72.01	83.54	5.0	1.50	1.50	26.23	0.282	Dark green
110	83.19	102.00	5.0	1.80	1.80	26.78	0.246	Dark green
115	110.27	112.21	5.0	1.90	2.10	29.54	0.236	Green
120	120.90	115.70	4.0	2.00	2.20	31.17	0.221	Green
125	125.40	120.70	4.0	2.10	2.50	35.55	0.218	Green
130	128.50	121.91	4.0	2.10	2.75	37.80	0.192	Green
135	130.90	112.21	3.0	2.10	2.70	37.81	0.185	Light green
140	130.92	112.21	3.0	2.10	2.70	38.12	0.185	Light green
S.Em±	15.75	5.45	1.6	0.05	0.09	3.2	0.05	
$CD_{0.05}$	42.12	15.55	4.22	1.55	2.1	10.5	1.12	

Table 2. Bio-Chemical characteristics of Assam lemon at different stages of maturity

Days after fruit set (DAFS)	TSS(^{0} Brix)	Acidity (%)	TSS/acid ratio	Ascorbic acid (mg/100g)	Pectin %
90	6.0	1.54	3.89	40.98	2.33
95	6.0	1.60	3.75	45.54	2.54
100	6.0	2.37	2.53	49.98	2.61
105	6.10	2.45	2.40	51.27	2.77
110	6.50	2.79	2.32	56.98	3.12
115	6.50	3.07	2.32	63.45	3.36
120	6.37	3.12	2.04	69.92	3.38
125	6.30	3.41	1.84	63.45	3.30
130	6.20	3.12	1.99	56.55	3.28
135	5.96	2.11	2.81	41.50	3.25
140	5.50	1.98	2.78	40.20	3.20
S.Em±	0.18	0.28	0.85	4.12	0.25
$CD_{0.05}$	0.42	0.65	1.52	11.88	0.70

4. CONCLUSIONS

It is concluded that maturity of the fruit in Assam lemon could be assessed by both quantitative and qualitative means of physico-chemical characteristics of developing lemon fruits. Studies on changes in physico-chemical characteristics of Assam lemon, during fruit development and maturation indicated that fruits reached complete maturity at 130 DAFS and considered optimum for harvesting maturity. Results also indicated that most of the quality characteristics were retained upto 140 DAFS and harvesting can be extended till 140 DAFS.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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