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Surjit Moni Deka
Department of Biochemistry and Agricultural Chemistry, Assam Agricultural University, Jorhat, Assam, India

Ananta Madhav Baruah
Department of Biochemistry and Agricultural Chemistry, Assam Agricultural University, Jorhat, Assam, India

Samindra Baishya
Department of Biochemistry and Agricultural Chemistry, Assam Agricultural University, Jorhat, Assam, India

Corresponding Author:
Surjit Moni Deka
Department of Biochemistry and Agricultural Chemistry, Assam Agricultural University, Jorhat, Assam, India

Physio-chemical changes in Khasi Mandarin (*Citrus reticulata* Blanco) during ripening

Surjit Moni Deka, Ananta Madhav Baruah and Samindra Baishya

Abstract
Physio-biochemical constituents of the fruit khasi Mandarin (*Citrus reticulata* Blanco) cultivated in Assam was studied during different stages of development following 90 days after fruit setting (DAFS) to 210 DAFS. The parameters such as fruit weight, diameter, volume, pulp weight, peel weight and pulp-peel ratio as well as moisture, juice percentage, TSS, titratable acidity, sugar and juice pH were evaluated. An increase in fruit weight (23.46 to 78.32 g), pulp weight (16.98 to 61.06 g), peel weight (6.48 to 17.26 g), fruit diameter (3.33 to 5.20 cm) and volume (24.66 to 78.67 cc) were observed from 90 DAFS to 210 DAFS respectively. Other parameters like Pulp: peel, moisture content, TSS, total soluble, reducing and nonreducing sugar, juice content and juice percentage also increased as the fruit matured. Reducing, non-reducing and total sugar were found to augment from 1.65, 0.87 and 2.52 percent at 90 DAFS to 2.85, 3.86 and 6.7 percent at 210 DAFS respectively.

Keywords: Khasi mandarin, physical, biochemical, DAFS, ripening, maturity

Introduction
Citrus fruits are one of the most economically important cultivated fruit crops in both tropical and subtropical regions in the world due to their unique nutritional profile. Khasi mandarin (*Citrus reticulata Blanco*) is widely cultivated and commercialized variety of mandarin grown in the North-eastern region of India and hold first place among all cultivated species of citrus, with respect to area and production in India (Yadav, 2007) [28]. Assam and Meghalaya occupy the maximum area under the production of Khasi mandarin (Singh, 2016) [25]. The Khasi mandarin produced in North eastern region had been popular for its superior quality in respect of its flavour, juice content, sugar and acidity ratio as recorded by Deka (2018) [10]. The wide acceptance of Mandarin around the world as noted by Huang *et al.* (2010) [17] and Zhang *et al.* (2012) [30] was due to their delicious taste and medicinal properties that had long been used as traditional herbal medicine to inflammatory syndromes of the respiratory tract. Mandarin fruit is characterized by a peculiar sensory quality which is result of unique combination of sugar and organic acids (Wang *et al.* 1993) [27]. Palmer and List (1973) [20], Evans *et al.* (1983) [15] Blanco *et al.* (1996) [7] and Camara *et al.* (1994) [9] documented that the organic acids profile was considered as indicator of fruit ripening, bacterial activity, adulteration and useful index of authenticity in fruit products because of their lower susceptibility to change during processing and storage when compared with other phytochemicals components of fruits. It was found that in citrus fruit the commercial maturity indices were highly variable and dependent on growing region, market demand and varieties. Devkota *et al.* (1982) [12] reported that the maturity standards could vary from region to region. According to Deshmukh *et al.* (2016) [11] under different altitudes the determination of the criteria for fruit maturation was quite complex as the internal changes occurred in the fruit pulp and external colouration took place on fruit peel. Citrus fruit does not continue to mature when detached from the mother plant and placed in storage, because it has no carbohydrate reserve. However, the stages of development at which citrus fruit is harvested have considerable effect on total acid and other quality aspects as reported by Soni and Randhawa (1969) [26]. Rokaya *et al.* (2016) [23] recorded that the most important and reliable judging criteria of fruit maturity in mandarin were fruit weight, external fruit colour, firmness, TSS, acidity, TSS/Acid ratio and vitamin C. Till date, no systematic approach has been made to determine the standard of maturity based on physical and biochemical data of raw mandarin fruit till maturity of the Khasi mandarin grown in this region.

Therefore, the aim of present study is to develop a complete physical and biochemical database of Khasi mandarin fruit during different developmental stages of fruit from 90 days of fruit set to the 210 days of fruit set (mature fruit) grown in north east region of country. In the present study, the change in physical parameters such as weight, volume of the fruit along with bio chemicals parameters *viz.* pH, TSS, TSS and sugar content of fruit during the development period were studied.

Materials and Methods

Freshy washed fruits in triplicate were subjected for the analysis of physical parameters such as weight, volume, diameter, pulp weight, peel weight, pulp: peel ratio by standard protocols. Weight of pulp and peel was measured according to the protocol as described by Bhuyan (1996) [6] from which the pulp peel ratio was calculated using the following formula:

$$\text{Pulp: Peel} = \frac{\text{Pulp weight (g)}}{\text{peel weight (g)}}$$

Furthermore, fruit volume was determined by traditional water displacement method. The juice extraction was done by mechanical pressing and the amount of juice was measured using measuring cylinder as described by Bharali (2016) [4]. The percentage of juice per fruit was determined by dividing the volume of the fruit juice by weight. After removing the peels, the pulps were sliced and mixed well. A part of the composite sample was immediately processed for analysis of chemical constituents *viz.*, moisture, total soluble solids (TSS), titratable acidity, sugars and juice pH. The moisture content was estimated using standard oven dry method. In a clean, dried and weighed (W1) crucible, 5 g fruit tissue was added. Final weight (W2) was recorded after placing the crucible in hot air oven at 70 °C. Then, moisture content was calculated as follows.

$$\text{Moisture content (\%)} = (W1 - W2 / W1) \times 100.$$

The TSS was measured by digital refract meter (Model:PR-32α, ATAGO), the titratable acidity and sugar content were determined by standard methods of analytical chemists (AOAC 2000) [1].

Results and Discussion

Variation in physical parameters *viz.* weight, diameter, volume and percentage of peel, pulp percentage and juice content throughout the development of the fruit (90 DAFS to 210 DAFS) are represented in Table 1. The fruit weight along with pulp and peel weight followed a increasing trend (Fig. 1) as the fruit matured. 90 days fruits were found to have 23.46 g, 6.48 g and 16.98 g of whole fruit, pulp and peel respectively which gradually increased to 78.32 g (whole fruit), 61.06 g (Pulp) and 17.26 g (Peel) when the fruit attained maturity. In the present study, fruit weight, fruit volume and fruit diameter found to increase progressively with the maturity of the Khasi mandarin fruits (Fig. 1). This increase in fruit weight may be due to the accumulation of juice in the fruit. Again, the increase in fruit weight and fruit volume could be the result of the increase in size of the cell and accumulation of food substances in inter cellular spaces of fruit (Bollard, 1970) [8]. Similar trends of increasing fruit weight were reported by Deshmukh *et al.* (2016) [11] in Kinnow mandarin grown in different altitudes of Meghalaya. In the present study, highest (78.67 cc) and lowest (24.66 cc) fruit volumes were recorded at 210 DAFS and 90 DAFS respectively. Bhatnagar *et al.* (2012) [5] reported similar increasing trend of fruit volume in Nagpur mandarin during fruit development. The fruit diameter increased in all stages of fruit development towards the maturity. Diameter of the fruit was increased from 3.2 cm (90 DAFS) to 5.20 cm (210 DAFS).

Table 1: Changes in physical parameters of Khasi mandarin fruit during ripening

Days after fruit set (DAFS)	Whole Fruit weight (g)	Fruit diameter (cm)	Fruit volume (cc)	Peel weight (g)	Peel (%) of whole fruit	Pulp weight (g)	Pulp (%) of whole fruit	Pulp: Peel ratio	Juice content per fruit (ml)	Juice percentage per fruit (%)
90	23.46	3.13	24.66	6.48	27.61	16.98	72.39	2.62	6.87	29.23
120	37.51	3.97	38.33	9.19	24.51	28.32	75.49	3.08	12.63	33.67
150	58.35	4.33	59.33	13.45	23.05	44.9	76.95	3.33	22.20	38.04
180	69.23	4.77	69.67	15.48	22.37	53.74	77.63	3.47	28.63	41.36
210	78.32	5.20	78.67	17.26	22.04	61.06	77.96	3.52	36.03	46.03
S.Ed (±)	0.2316	0.1333	0.4714	0.1448	0.3359	0.2248	0.3359	0.0543	0.4184	0.7219
CD (0.05)	0.5161	0.2970	1.0503	0.3227	0.7486	0.5010	0.7486	0.1211	0.9323	1.6085

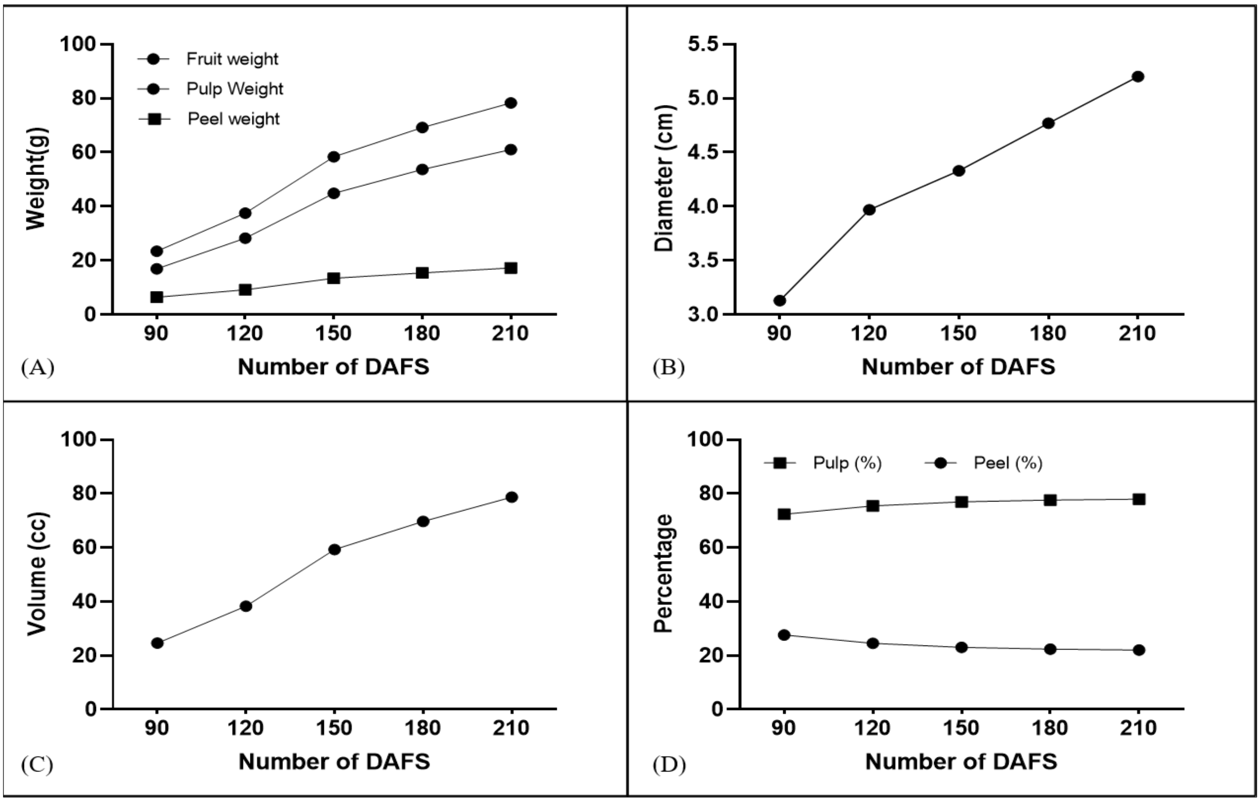

Fig 1: Change in physical parameters during fruit ripening in various developmental stages (A) Relationship between changes in fruit pulp and peel weight (B) Change in diameter of fruit from 90 DAFS to 210 DAFS (C) Change in volume of fruit from 90 DAFS to 210 DAFS (D) Change in pulp and peel percentage

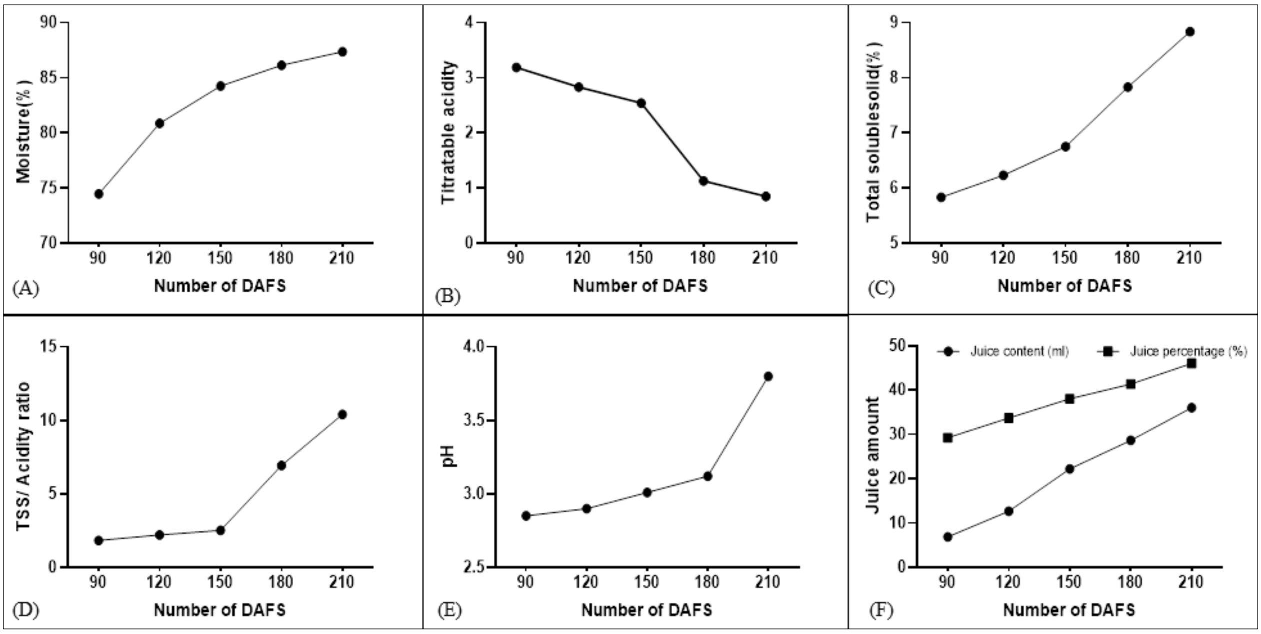

Fig 2: Change in biochemical in mandarin fruit from 90 DAFS to 210 DAFS (A) seasonal change in moisture content (B) change in TA (C) Seasonal change in TSS (D) Change in TSS/TA Ratio (E) Change in pH (F) Change in Juice amount at each developmental stage.

However, an antagonistic trend in pulp and peel percentage were observed (Fig 1) as the fruit matured. Highest pulp percentage (77.96%) was recorded at 210 DAFS and highest peel percentage (27.61%) was recorded at early stage of maturity of 90 DAFS. In the current investigation, juice content was also found to increase towards the fruit maturity. Similar increasing trend of juice content was also reported by Bhatnagar *et al.* (2012) [5] and Deshmukh *et al.* (2016) [11] in Nagpur mandarin and Khasi mandarin. The changes of biochemical parameters from 90 DAFS to 210 DAFS are represented in Table 2. Moisture content on fresh pulp weight basis had been increased significantly since 90 DAFS to 180 DAFS and then no significant increase was observed. The highest 87.37% and the lowest 74.48% moisture content were recorded at 210 DAFS and 90 DAFS respectively. The moisture content was increased towards maturity. TSS content was found to increase in all stages of fruit development towards maturity (Fig 2).

Table 2: Changes in biochemical characters of Khasi mandarin fruit during ripening

Days after fruit set (DAFS)	Moisture content (%)	Total soluble solid (%)	Titratable acidity (%)	TSS/ Acidity ratio	pH	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)
90	74.48	5.83	3.19	1.83	2.85	1.65	0.87	2.52
120	80.87	6.23	2.83	2.20	2.90	1.91	1.30	3.21
150	84.25	6.75	2.54	2.52	3.01	2.14	1.84	3.99
180	86.14	7.83	1.13	6.93	3.12	2.19	3.24	5.43
210	87.37	8.84	0.85	10.40	3.80	2.85	3.86	6.70
S.Ed (±)	0.5711	0.0181	0.0111	0.1102	.0.0141	0.0109	0.0117	0.0126
CD (0.05)	1.2726	0.0404	0.0248	0.2457	0.0315	0.0244	0.0261	0.0281

The highest (8.84%) and the lowest (5.83%) TSS were recorded at 210 DAFS and 90 DAFS respectively. Similar trends were recorded by Deshmukh *et al.* (2016) [11] and Bhatnagar *et al.* (2012) [5] in Kinnow mandarin grown in Meghalaya and in Nagpur mandarin in Maharashtra. The TSS: acidity ratio was found to be increased significantly throughout the maturity period from 1.83 to 10.40 (Fig 2). Such increase trend in TSS: acidity ratio may be due to the increasing rate of deposition of polysaccharides and decreasing rate of acidity with the advancement of maturity period. Almost similar result of TSS: acidity ratio was reported by Rokaya *et al.* (2016) [23] and Deshmukh *et al.* (2016) [11] in mandarin. The present study also revealed that the pH content of the fresh juice increased till the last stage of maturity from 2.85 to 3.80. The result of present investigation is well comparable with the findings of Sinclair *et al.* (1994) [24]. They reported the similar trends of change in pH during the development of *Valencia* orange. Data representing the amount of reducing, non-reducing and total sugar during fruit development is represented in the Table 2. A significant increase in concentration total soluble sugar, reducing sugar and non-reducing sugar were observed in the fruits from 90 DAFS to 210 DAFS. Fruits at maturity were found to contain highest 6.70% total soluble sugar, 2.85% reducing and 3.86% non-reducing sugar. Similar trends of increasing sugar composition were reported by Ram (2001) [21] and Deshmukh *et al.* (2016) [11] in Kinnow mandarins.

Conclusion

The present study was conducted to achieve the existing knowledge gap of non-availability of biochemical data of mandarin fruit during various developing stages. Throughout the development process, physical parameters such as weight, diameter and volume of the fruit are found to increase gradually. Fruits that are harvested at 210 DAFS have a peculiar mandarin taste and fruits are found to have minimum amount of TA and maximum TSS and TA ratio which determines sweetness, firmness and marketability of the fruits. Fully developed fruit is found to be a rich source of sugar as compared to their earlier developing stages.

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References

1. AOAC. Official Methods of Analysis 17th Ed. Washington, DC; c2000.
2. Albertini MV, Carcouet E, Pailly O, Gambotti C, Luro F, Berti L. Changes in organic acids and sugars during early stages of development of acidic and Acidless citrus fruit. Journal of Agricultural and Food Chemistry. 2006;54(21):8335-8339.
3. AOAC. Official methods of analysis. 13th Ed. Washington, DC; c1980.
4. Bharali R. Morpho-biochemical characterization of pummelos (*Citrus grandis* L.) of Assam. Ph.D. (Agri.) thesis, Assam Agricultural University, Jorhat; c2016.
5. Bhatnagar P, Jitendra S, Jain MC, Bhim S, Manmohan JR, Dashora LK. Studies on seasonal variations in developing fruits of Nagpur mandarin (*Citrus reticulata* Blanco) under Jhalawar conditions. Asian Journal of Horticulture. 2012;7(2):263-265.
6. Bhuyan, H. Changes in physio-chemical composition of rough lemon (*Citrus jambhiri* Lush) fruit at different development stages. M.Sc. (Agri) thesis, Assam Agricultural University, Jorhat; c1996.
7. Blanco D, Quintanilla ME, Mangas JJ, Gutierrez MD. Determination of organic acids in apple juice by capillary liquid chromatography. Journal of Liquid Chromatography and Related Technologies. 1996;19(16):2615-2621.
8. Bollard EG. The physiology and nutrition of developing fruits. The Biochemistry of Fruits and Their Products. 1970;1:387-425.
9. Camara MM, Die C, Torija ME, Cano MP. HPLC determination of organic acids in pineapple juices and nectars. Zeitschrift Für Lebensmittel-Untersuchung Und – Forschung. 1994;198(1):52-56.
10. Deka S, Sehgal M, Kakoti RK, Barbora AC. Module analysis for insect pest management of Khasi mandarin (Citrus *reticulata* Blanco) under climatic conditions of north-eastern India. Journal of Entomology and Zoology studies. 2018;6(4):857-861.
11. Deshmukh NA, Patel RK, Rymbai HH, Jha AK, Deka BC. Fruit maturity and associated changes in Khasi Mandarin (*Citrus reticulata*) at different altitudes in humid tropical climate. Indian Journal of Agricultural Sciences. 2016;86(7):854-859.
12. Devkota RP, Grewal SS, Dhatt, AS. The Quality of Citrus Fruits as Affected by Varieties and Growing Condition. Punjab horticultural journal. 1982;22:131-135.
13. Dubois M, Gilles KA, Hamilton JK, Rebers PA, Smith F.Colorimetric Method for Determination of Sugars and Related Substances. Analytical Chemistry. 1956;28(3):350-356.
14. Ergonul GP, Nergiz C. Determination of organic acids in olive fruit by HPLC. Czech Journal of Food Sciences. 2010;28(3):202-205.
15. Evans RH, Soestbergen AWV, Ristow KA. Evaluation of Apple Juice Authenticity by Organic Acid Analysis. Journal of AOAC International. 1993;66(6):1517-1520.
16. Fernie AR, Martinoia E. Malate. Jack of all trades or

master of a few? Phytochemistry. 2009;70(7):828-832.

17. Huang YS, Ho SC. Polymethoxy flavones are responsible for the anti-inflammatory activity of citrus fruit peel. Food Chemistry. 2010;119(3):868-873.
18. Legua P, Forner JB, Hernández F, Forner-Giner MA. Total phenolics, organic acids, sugars and antioxidant activity of mandarin (*Citrus clementina* Hort. ex Tan.): Variation from rootstock. Scientia Horticulturae. 2014;174(1):60-64.
19. Medeiros DB, Barros KA, Barros JAS, Omena-Garcia RP, Arrivault S, Sanglard L. *et al*. Impaired malate and fumarate accumulation due to the mutation of the tonoplast dicarboxylate transporter has little effects on stomatal behavior. Plant Physiology. 2017;175(3):1068-1081.
20. Palmer JK, List DM. Determination of Organic Acids in Foods by Liquid Chromatography. Journal of Agricultural and Food Chemistry. 1973;21(5):903-906.
21. Ram L. Physiological And Biochemical Changes During Fruit Maturation Of Kinnow Mandarin On Tree And In Storage. PhD (Agri) thesis, Chaudhary Charan Singh Haryana Agricultural University; Hisar; c2001.
22. Robertson JA, Ryden P, Louise Botham R, Reading S, Gibson G, Ring SG. Structural properties of diet-derived polysaccharides and their influence on butyrate production during fermentation. LWT - Food Science and Technology. 2001:34(8):567-573.
23. Rokaya PR, Baral DR, Gautam DM, Shrestha AK, Paudyal KP. Effect of Altitude and Maturity Stages on Quality Attributes of Mandarin (*Citrus raticulata* Blanco). American Journal of Plant Sciences. 2016;7(06):958-966.
24. Sinclair WB, Ramsey RC. Changes in the Organic-Acid Content of Valencia Oranges During Development. Botanical Gazette. 1944;106(2):140-148.
25. Singh AK, Meetei NT, Singh BK, Mandal N. Khasi mandarin: its importance, problems and prospects of cultivation in North-eastern Himalayan region. International Journal of Agriculture, Environment and Biotechnology. 2016;9(4):573.
26. Soni SL, Randhawa GS. Morphological and chemical changes in the developing fruits of lemon *Citrus limon* (L.) Burn. F. Indian journal of Agricultural Science. 1969;39:813-829.
27. Wang T, Gonzalez AR, Gbur EE, Aselage JM. Organic Acid Changes During Ripening of Processing Peaches. Journal of Food Science. 1993;58(3):631-632.
28. Yadav PK. Fruit production technology. Edn 1, International book distribution Co., New Delhi; c2007. p. 203-221.
29. Zell MB, Fahnenstich H, Maier A, Saigo M, Voznesenskaya EV, Edwards GE, *et al*. Analysis of Arabidopsis with highly reduced levels of malate and fumarate sheds light on the role of these organic acids as storage carbon molecules. Plant Physiology. 2010;152(3):1251-1262.
30. Zhang JY, Zhang Q, Zhang HX, Ma Q, Lu JQ, Qiao YJ. Characterization of polymethoxylated flavonoids (PMFs) in the peels of “Shatangju” mandarin (*Citrus reticulata* Blanco) by online high-performance liquid chromatography coupled to photodiode array detection and electrospray tandem mass spectrometry. Journal of Agricultural and Food Chemistry. 2012;60(36):9023-9034.