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The comparison of carbohydrate and mineral changes in three cultivars of kiwifruit of Northern Iran during fruit development

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Abstract

According to the result of this study, there was a significant increase in the amount of sugars including rhamnose, glucose and mannose from October for Abbot and Hayward and from August for Allison until harvesting time (late November). During one month of post harvesting time, the fruits showed no significant changes in sugar concentration except for the Hayward that showed a significant increase of glucose and mannose concentration. The concentration of fructose and inulin in Allison and Hayward did not show any significant changes during the investigated months except a decline on August and then remained constant at the first level. The concentration of these sugars in Abbott showed a similar pattern i.e. a reduction in August followed by a significant increase until harvesting time, and then remained at constant level. Soluble solid content (SSC) as an indicator of fruit maturity, in Allison was significantly more than other cultivars in harvesting time, however, this difference was not significant in late December among cultivars. The mineral analysis of the fruits indicated that the concentration of iron and phosphorus of the kiwifruit cultivars were not significantly different but, potassium concentration in Hayward and calcium concentration in Allison were significantly more than other cultivars.

Keyword: Kiwifruit development, inulin, manose, minerals, carbohydrates, Hayward

Introduction

There are more than 70 Actinidia species but, only three species of *A.deliciosa*, *A. chinensis* and *A.arguta* have been commercially exploited to date (Atkinson & Macrae, 2007). Iran is a country with the most significant increases (>20%) in the planted area during the previous decade (Atkinson & Macrae, 2007). The fruit of *Actinidia deliciosa* is highly rich in vitamin C (180 mg/100 g in Hayward), minerals, carbohydrates and proteins (Rush et al., 2002). Meanwhile Gallego & Zarra (1997) investigated changes in water-soluble polysaccharides composition and structure of kiwifruit (cv. Hayward) cell walls during fruit development. They found that water-soluble polysaccharide content increased linearly during the entire growth period. Uronic acid and glucose were the main sugar at this time and the large amount of glucose presented at the final stage of fruit growth. Additionally, Li et al. (2006) examined changes of pectin, hemicelluloses and cellulose in the cell-wall of outer pericarp tissues of Hayward during fruit development. They concluded that the molecular-mass of pectic polysaccharides decreased during fruit enlargement and maturity. The high molecular-mass components of hemicelluloses detected at the early stage of fruit enlargement were degraded at the late stage of fruit enlargement, but then remained stable at the much lower molecular-mass till fruit maturity. Sugars and mineral content of some kiwifruit cultivars during cold storage have also been examined (Manolopoulou & Papadopoulou, 1998; Boldingh et al., 2000; Zolfaghari et al., 2008; Nishiyama et al., 2008). This study for the first time, investigated the amount of some carbohydrates including glucose, mannose, rhamnose, fructose and inulin, soluble solid content (SSC) and also some of mineral elements such as potassium (K), phosphorus (P), calcium (Ca) and iron (Fe) in three cultivars of *Actinidia deliciosa* including Abbott, Allison and Hayward cultivated in the north of Iran, during six months of fruit development. These sugars and minerals have important structural and functional rules in plants. The determination of the best time of kiwifruit consumption with higher concentration of the materials leads to have the fruits with higher nutritious value.

Materials and methods

Fruit sampling

Kiwifruit samples of the cultivars of Abbot, Allison and Hayward were obtained from research center gardens close to the city of Tonekabon at the north of Iran, from early July to late December 2008. The fruits were harvested in late November and were stored in ambient temperature (average day/night temperature 15/8˚C, respectively) for one month. Collected fruits were stored in -20˚C until different assays were performed.

Carbohydrates determination

The samples of outer pericarp of kiwifruits (0.1 g) were grounded in 3 ml distilled water and then diluted 5 times. Rhamnose, glucose and mannose were determined by Dubois et al. (1956) method. Briefly, the kiwifruit solution (0.5 ml) and the phenol solution %5 (0.5ml) were added to glass tubes then 2.5 ml of concentrated sulfuric acid was added slowly to the tubes. The tubes were then incubated for 15 min at room temperature (~25°C) and the absorption at 480, 485 and 490 nm, for determination of Rhamnose, Glucose and Mannose respectively, in a spectrophotometer (GBC, Cintra 6. Australia) were read. Distilled water plus phenol solution %5 (0.5ml) and concentrated sulfuric acid were used as blank sample.

Fructose and Inulin determination

The samples of outer pericarp of kiwifruits (0.1 g) were grounded in 3 ml distilled water and then diluted 10 times. Fructose and Inulin were measured using the anthrone reaction method (Jermyn 1956). Briefly, the diluted kiwifruit solution (0.5 ml) and anthrone reagent, anthrone % 0.02 in sulfuric acid %70 (2.5ml) were added to glass tubes. The tubes were then incubated for 15 min at room temperature (~25°C) and then for 8 min in boiling water bath. All tubes were allowed to cool down to room temperature before reading the absorption at 625nm.

Mineral determination

Full mature kiwifruit was turned into ash at 70°C for 72 hours. The ash was digested by nitric-percholoric acid digestion method (Johnson & Ulrish, 1959). Briefly, the ground samples (1g) dissolved in 4ml of nitric-percholoric acid and heated on a hot plate for 10 h at about 120°C until colorless solution was obtained. The solution was reached to volume 20 ml with deionized water. The K, Ca and Fe contents were evaluated using a model 603 atomic absorption spectrophotometer (Perkin Elmer). Phosphor concentration was determined using Reagent sodium molybdate (Boltz & Lueck, 1958) by

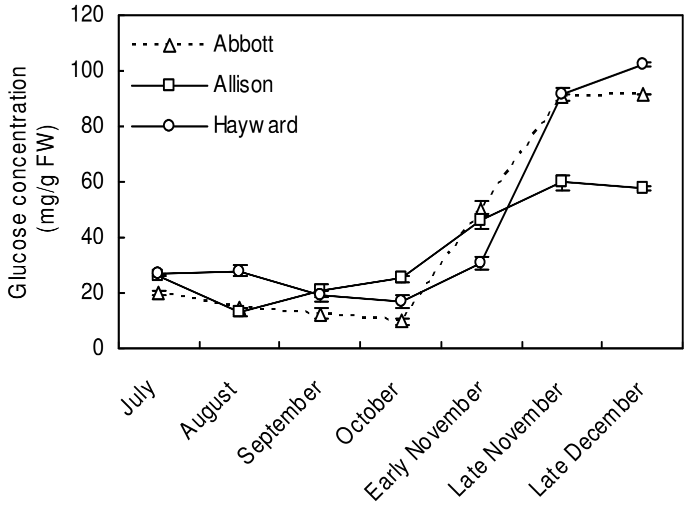

Fig 1. Glucose content in outer pericarp of the three kiwifruit cultivars (Abbott, Allison and Hayward) from early July to late December 2007 (mg/g fresh weight). Results are mean of 3 determinations ± SD.

spectrophotometer (GBC, Cintra6. Australia). Concentration of each element was calculated according to mg/g of dry weight.

Soluble solid content

Soluble solid content (SSC) of each kiwifruit sample during six months of fruit development were calculated using digital refrectometer (Quartz-Ceti-Belgium).

Statistical Analysis

The data were analyzed by Duncan's multiple range test at $P<0.05$ using the SPSS software. All the analyses were repeated three times.

Results

Sugars content

Changes in the content of glucose, mannose and rhamnose in the investigated cultivars showed almost the same pattern. However, the concentration of these sugars significantly increased from October for Abbot and Hayward and from August for Allison until harvesting time (late November). During one month of post harvesting time (late December), the fruits showed no significant changes in sugar concentration except for the Hayward that showed a significant increase in the concentration of glucose and mannose (Fig 1). The pattern of changes for rhamnose and mannose of the cultivars were almost the same (data are not shown). Among the cultivars, Allison showed the lowest concentration of these sugars compared with two other

Table 1. Soluble solid content (°Brix) of the three kiwifruit cultivars (Abbott, Allison and Hayward) from early July to late December. Results are mean of 3 determinations ± SD. Different letters in the same column show significant differences at P<0.05.

Months	Abbott (brix)	Allison (brix)	Hayward (brix)
July	0.3 ± 0.01 a	0.7 ± 0.01 a	0
August	0.5 ± 0.03 a	3.8 ± 0.13 b	0.5 ± 0.02 a
September	2.3 ± 0.17 b	4.2 ± 0.24 c	1.1 ± 0.07 b
October	2.6 ± 0.23 b	4.8 ± 0.12 c	2.5 ± 0.14 c
Early November	5 ± 0.28 c	5.2 ± 0.12 d	3.4 ± 0.14 d
Late November	8 ± 0.67 c	9.2 ± 0.74 e	6 ± 0.01 e
Late December	11.8 ± 0.34 d	11.3 ± 0.72 f	11.6 ± 0.43 f

cultivars at harvesting time (late November) and post harvesting time (Fig 1). The concentration of fructose and inulin in Allison and Hayward did not show any significant changes during the investigated months except a decline in August and then remained constant at the first level. The concentration of these sugars in Abbott showed a similar pattern i.e. a reduction in August followed by a significant increase until harvesting time, and then remained at constant level (Fig 2). The pattern of changes for fructose content of the cultivars were almost the same (data are not shown).

In all cultivars, the content of mannose and glucose in the outer pericarp of the fruits at harvesting time, November, were significantly higher followed by rhamnose, inulin and fructose, respectively (Fig 3).

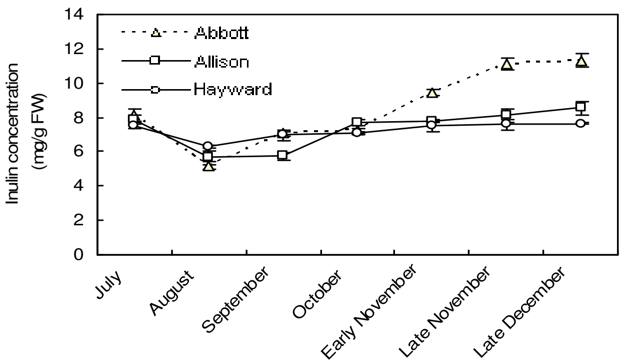

Fig 2. Inulin content in outer pericarp of the three kiwifruit cultivars (Abbott, Allison and Hayward) from early July to late December 2007 (mg/g fresh weight). Results are mean of 3 determinations ± SD.

Soluble solid content (SSC)

All three investigated cultivars showed increasing pattern of SSC during fruit development and ripening. The amount of SSC (°Brix) in Allison was significantly higher than two other cultivars at the harvesting time, November, followed by Abbott and Hayward (9.2, 8 and 6 respectively). However, after one month post harvesting time, there were no significant differences in SSC content of the three cultivars (Table 1).

Minerals content

According to the results, the concentration of Fe and P of the full ripened kiwifruits of all three cultivars were low and not significantly different from each others. Among the investtigated cultivars, Hayward showed the highest content of potassium (20.83 ± 1.19 mg/g. DW). Also, the concentration of calcium in Allison was significantly higher than two other investigated cultivars (Table 2).

Discussion

Sugars content

According to the result of this study the little concentration of investigated sugars was high in the first month of sampling for Abbot and Allison and first and second months for Hayward, and then decreased until October for Abbott and Hayward, and August for Allison following with a significant increase until harvesting time. Boldingh et al. (2000) reported that glucose peak in early fruit development in *A. deliciosa* coincides with a peak in fruit water content. By that time, the major cell division phase in fruit development has ended and the most rapid fruit growth rate was due to cell expansion. Transient accumulation of sugars at the early stage of fruit growth may lead to an increase in osmotic pressure followed by an increase in cell turgor at the cell expansion phase (Boldingh et al., 2000).

In kiwifruit, carbohydrates are mostly accumulated in the form of starch during fruit development. At harvesting time, most of the carbohydrate content hydrolyzed into simple sugars during ripening (Jordan et al., 2000; Atkinson & Macrae, 2007). Therefore we expected an increase in sugar content during post harvest time that was coincident with fruits ripening but, the cultivars of Abbott and Allison showed no changes in sugar contents. With the exception of *A. arguta*, ripened fruit of Actinidia species accumulated hexoses rather than sucrose, which is similar to ripened strawberries and apple (Boldingh et al., 2000). The ripened fruit of *A. arguta* accumulate mainly sucrose followed by glucose and

Table 2. Minerals content (mg/g DW) of the full ripened fruits of three cultivars of Abbott, Allison and Hayward. Results are mean of 3 determinations ± SD. Different letters in the same column show significant differences at P<0.05.

Cultivars	K	Ca	P	Fe
Abbott	10.80 ± 1.71 a	2.93 ± 0.34 a	0.73 ± 0.12 a	0.06 ± 0.01 a
Allison	13.53 ± 1.07 b	4.19 ± 0.66 b	0.89 ± 0.15 a	0.07 ± 0.01 a
Hayward	20.83 ± 1.19 c	2.57 ± 0.45 a	1.03 ± 0.11 a	0.06 ± 0.01 a

fructose (Nishiyama et al., 2008). These differences in balances between different sugars, and sugars and starch at different stages of fruit development may be due to variations in the activities of invertase, sucrose synthase, hexokinase and fructokinase and, perhaps, sucrose-phosphate synthase among the species (Boldingh et al., 2000). In this investigation, in all examined cultivars, the content of mannose and glucose in the outer pericarp of the fruits at harvesting time were significantly higher followed by Rhamnose, Inulin and Fructose, respecttively. There have been many reports that confirmed in *A. deliciosa* fruits hexoses are the predominant sugars and glucose and fructose were present in approximately equal amount (Jordan et al., 2000; Nishiyama et al., 2008). However, Boldingh et al. (2000) reported that *A. deliciosa* was the exception, where glucose constituted 60% of the total sugars. The different results found in this study regarding high concentration of mannose may be related to the way that we determined the amount of this sugar. Mannose is an initial component in vitamin C synthesis pathway. In plants, ascorbate synthesis mostly occurs through the L-galactose pathway, in which GDPD-mannose is converted to L-ascorbate (Giovannoni, 2007).

According to the result of this study, Hayward had the highest total investigated sugar content among the three examined cultivars. A different result was reported by Nishiyama et al. (2008), who determined the concentration of glucose, fructose and sucrose in some of *A. deliciosa* cultivars, so that the fruit of Abbott showed higher total sugar content followed by Hayward. In this study, Abbott showed the highest content of inulin and fructose compared with two other cultivars.

It has been reported that the dietary fiber, such as inulin, in kiwifruit is about 3.4 g/100 g, thus kiwifruit is a good source of dietary fiber and has a laxative effect especially in the elderly people (Chan et al., 2007).

Soluble solid content (SSC)

Soluble solid content of kiwifruit is considered as an index of fruit maturity, and fruits with a high SSC store well with better flavor after ripening (Tavarini et al., 2008). In this investigation, increasing pattern of SSC during fruit development and ripening confirms the finding that SSC increases at ripening stage of fruit development (Park et al., 2006; Tavarani et al., 2008). At the harvesting time, Allison and Hayward showed the highest and lowest SSC (9.2 and 6). Since Allison is an early ripening and Hayward a late ripening cultivar this result was expectable. During fruit ripening and softening process, starch is broken down to the simple soluble sugars and also the amount of soluble pectin will increase (Prasanna, 2007), leading to fruit softening. In this study after one month post harvesting time, there were no significant differences in SSC content of the three cultivars.

Minerals content

In all studied cultivars, Potassium was the main mineral quantitatively. Among the investigated cultivars, Hayward showed the highest and Abbott the lowest content of potassium (20.83 ± 1.19 and 10.8 ± 1.71 mg/g. DW, respectively). According to the report of Zolfaghari et al. (2008), Allison had the highest and Hayward had the lowest K (372.271 and 279.890 mg 100 g−1 fresh weight, respectively). Kiwifruit is a good source of potassium, as a cofactor of more than 90% of plant enzymes, and in some reports the amount of this element is considered as equal as banana's (Mohammadian & Aliakbar, 2007) and almost 2 times more than apple's potassium content (Okamoto & Goto, 2005).

The results indicated that the concentration of Fe and P of the full ripened kiwifruit were low and not significantly different among the examined cultivars. However, since Fe is a micro-element in plants, low concentration of this element among the cultivars was expectable.

Among the investigated cultivars, Calcium (Ca) concentration in Allison (4.19 ± 0.66 mg/g. DW) was significantly more than other cultivars (table 2). Previous studies showed that Ca and other divalent ions delay ripening and senescence of kiwifruit, however, the way in which divalent ions act is not yet completely understood (Cicco et al., 2008). The effect of Ca on firmness of kiwifruits was counteracted by the large amounts of nitrogen and potassium that are known to decrease fruit firmness (Amodio et al., 2007). We expected that the concentration of Ca in Hayward which ripens later than Allison was higher but, in contrary, the result showed higher amount of Ca in Allison. Calcium is an essential plant element involved in determining fruit quality of several fruits including kiwifruit (Montanaro, 2006). According to the result of Zolfaghari et al. (2008) Allison at harvesting time had the highest amount of Ca compared with Abbott and Hayward. The differences in mineral composition can be attributed to the genetic factor of the studied cultivars (Zolfaghari et al., 2008).

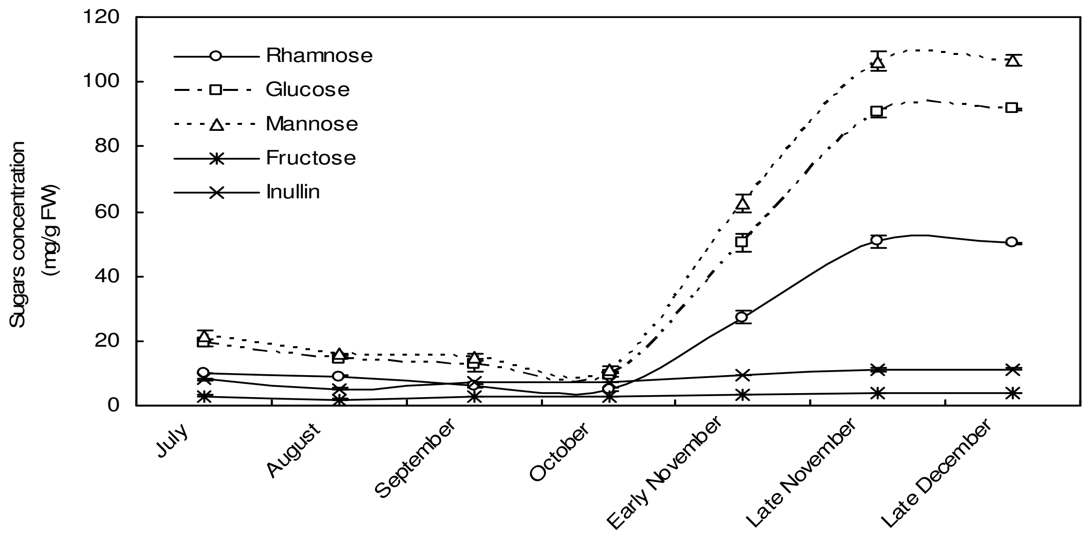

Fig 3. Glucose, Mannose, Rhamnose, Fructose and Inulin contents in outer pericarp of the three kiwifruit cultivars (Abbott, Allison and Hayward) from early July to late December 2007 (mg/g fresh weight). Results are mean of 3 determinations ± SD.

Conclusion

According to the results of the current study, among the examined cultivars, Hayward had the highest amount of potassium as well as total sugar content including rhamnose, glucose and mannose. Also, Abbott had the highest amount of inulin and fructose and Allison had the highest SSC and Calcium content at the harvesting time. The content of Fe and K content of full ripened kiwifruit were not significantly different among the investigated cultivars. However, additional research should be conducted regarding quantitative and qualitative differences of various kiwifruit cultivars growing in different environmental conditions to confirm cultivars with higher nutritious value.

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References

Amodio ML, Colelli G, Hasey JK, Kader AA (2007) A comparative study of composition and postharvest performance of organically and conventionally grown kiwifruits. Journal of the Science of Food and Agriculture. 87:1228–1236

Atkinson RG, Macrae EA (2007) Kiwifruit. In: Pua EC, Davey MR (ed) Transgenic Crops V. Springer Berlin Heiderberg. 60: 329-346.

Boldingh H, Smith GS, Klages K (2000) Seasonal concentrations of non-structural carbohydrates of five Actinidia species in fruit, leaf and fine root tissue. Annals of Botany. 85:469-476.

Boltz DF, Lueck CH (1958) Phosphoros. In: Choloro-metric determination of non-metals. Interscience. 29-46.

Chan AOO, Leung G, Tong T, Wong NY (2007) Increasing dietary fiber intake in terms of kiwifruit improves constipation in Chinese patients. World Journal of Gastroenterology. 13(35):4771-4775.

Cicco N, Dichio B, Xiloyannis C, Sofo A, Lattanzio V (2007) Influence of calcium on the activity of enzymes involved in kiwifruit ripening. ISHS Acta Horticulturae. 753:433-438.

Dubois M, Guilles KA, Hamilton JK, Rebers PA, Smith F (1956) Colorimetric method for determination of sugars and related substances. Anal Chem. 28:350-356.

Gallego PP, Zarra I (1997) Changes in cell wall composition and water-soluble polysaccharides during kiwifruit development. Annals of Botany, 79:695-701.

Giovannoni J (2007) Completing a pathway to plant vitamin C synthesis. Proceed Nat Aca Sci 104, 9109-9110.

Jermyn MA (1956) A new method for determining Ketohexoses in the presence of Aldohexoses. Nature. 177:38-39.

Johnson CM, Ulrich A (1959) Analytical methods for use in plant analysis. Bull. Calif. Agr Expt Sta. No. 766.

Jordan RB, Walton EF, Klages KU, Seelye RJ (2000). Postharvest fruit density as an indictor of dry matter and ripened soluble solids of kiwifruit. Postharvest Biology and Technology. 20: 163–173.

Li X, Nakagawa N, Nevins DJ, Sakurai N (2006) Changes in the cell-wall polysaccharides of outer pericarp tissues of kiwifruit during development. Plant Physiology and Biochemistry. 44: 115–124.

Mohammadian A M, Aliakbar A (2007) Quantitative analysis of minerals and vitamins in Iranian kiwifruits cultivars of Abbot, Bruno, Hayward, Monty and the comparison of their vitamins with Novel Thompson Orange. Iranian Journal of Biology, 20: 164-174.

Manolopoulou H, Papadopoulou P (1998) A study of respiratory and physico-chemical changes of four kiwi fruit cultivars during cool-storage. Food Chemistry, 63:529-534.

Montanaro G, Dichio B, Xiloyannis C, Celano G (2006) Light influences transpiration and calcium accumulation in fruit of kiwifruit plants (*Actinidia deliciosa* var. deliciosa). Plant Science, 170:520–527.

Nishiyama I, Tetsuo F, Atsuko S, Tadachika O (2008) Sugar and organic acid composition in the fruit juice of different Actinidia varietes. Food Science and Technology Research, 14:67-73.

Okamoto G, Goto S (2005) Juice constituents in *Actinidia arguta* fruits products in Shinjo, Okayama. Scientific Reports of the Faculty of Agriculture Okayama University, 94:9-13.

Park YS, Jung ST, Gorinstein S (2006) Ethylene treatment of Hayward kiwifruits (*Actinidia deliciosa*) during ripening and its influence on ethylene biosynthesis and antioxidant activity. Scientia Horticulturae. 108:22–28

Prasanna V, Prabha TN, Tharanathan RN (2007) Fruit ripening phenomena. Critical Reviews in Food Science and Nutrition. 47:1-19.

Rush E, Patel M, Plank LD, Ferguson LR. (2002) Kiwifruit promotes laxation in the elderly. Asia Pacific J Clin Nutr. 11:164-168.

Tavarini S, Degl'Innocenti E, Remorini D, Massai R, Guid L. (2008) Antioxidant capacity, ascorbic acid, total phenols and carotenoids changes during harvest and after storage of Hayward kiwifruit. Food Chemistry. 107:282-288.

Zolfaghari MSM, Barzegar M, Samadloiy H (2008) Physicochemical and enzymatic properties of five kiwifruit cultivars during cold storage. Food Bioprocess Technol. 2:114-126.