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Seasonal accumulation of total sugars, reducing Sugars and non-reducing sugars in the fruits of apple (*Malus domestics* Borkh.) cv. Fuji Zehn Aztec during fruit development

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Abstract
The effect of seasonal variation on sugar content of apple cultivar Fuji Zehn Aztec was studied over two growing seasons (2018-19) in the temperate climate of Kashmir valley at Division of Fruit Science, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology- Kashmir, Shalimar, Srinagar, J&K. The observations were recorded from 30DAFB (May 15) upto maturity (September 15) of developing fruits at fortnightly intervals. The mature fruits of apple had 10.49% total sugars, 8.37% reducing sugars and 2.12% non-reducing sugar contents, while at the first date of sampling period i.e.; May 15, the developing fruits of apple contain 3.42% total sugars, 3.24% reducing sugars and 0.18% non-reducing sugars. The trend observed in the present study indicated that the sugar content increased throughout the fruit development of apple fruits.

Keywords: Apple, maturity, seasonal variation, sugar content and temperate climate

Introduction
A famous proverb "An apple a day keeps the doctor away" focuses man's attention on the importance of apple in daily diet. Apple (*Malus* x *domestica* Borkh.), a prominent member of the temperate family (Rosaceae) of fruits grown across the globe is under cultivation since time immemorial. Apple has a basic chromosome number of 17 and is thought to have originated in Caucasus Mountains of South-Western Asia. Cultivation of apple in India is spread to an area of 3, 08, 000 hectares with an annual production of 2, 370, 000 MT and a productivity of 8.85MT/ha (Anonymous, 2019a) [3]. China and USA are leading countries of the world as far as apple production is concerned. India shares 4th rank in production of apples (Anonymous, 2019b) [4]. The region of Jammu and Kashmir has got prime position in the country where area under apple is approximately 1, 77, 258 hectares with a total production of 1, 953, 314 MT and a productivity of 11.52MT/ha (Anonymous, 2019c) [5] contributing an area and production of more than 83% and 60% respectively in the country.
Fruit sweetness is an important aspect of fruit quality. The sweetness of fruit mesocarp is highly dependent on its sugar composition, because sugars differ in sweetness (Genard *et al*. 2003) [9]. In fleshy fruits, soluble sugars, including sucrose, fructose and glucose, are not only essential for fruit growth and development but also central to fruit quality. Fruit taste and flavor is closely related to the composition and concentration of sugars and their balance with acids (Colaric, *et al*. 2005) [7]. As the composition and concentration of sugars at fruit maturity is determined by metabolic and transport processes during fruit development, understanding their dynamics is important for fruit quality improvement. The metabolism of cellular components important for fruit taste, such as sugars, organic acids, polysaccharides, pigments and aromatic compounds change drastically with fruit development (Yamaki, 1995) [12]. It is important to improve the quality of fruit and to increase the yields by controlling the sugar metabolism during fruit development. Fruits are strong sinks of assimilates in cropping apple trees and modify biomass partitioning in the plants. The carbohydrates assimilated in leaves are loaded into the growing apple fruit and finally accumulate in the vacuoles. Apple fruit enlarge and accumulate sugars after cell division has ceased (Yamaki & Ino, 1992) [13].

These sugars are formed in the flesh of apple fruit from sorbitol (Ackermann *et al*. 1992) [1], the main C-translocate between leaf and fruit, therefore sugar metabolism is closely associated with the various steps in the movement of assimilates (Yamaki, 1995) [12].

The objective of this work is to determine the influence of seasonal variation on accumulation of total sugars, reducing sugars and non-reducing during growth and development of apple fruit of Fuji Zehn Aztec cultivar.

Materials and Methods

Plant material and experimental design

Field trials were executed during the years 2018 & 2019 on 6 years old Fuji Zehn Aztec, raised on M9T337 root stock, planted at a distance of 1.5 m × 3 m (2222 plants/ha). The uniform cultural practices as per package of practices were given to experimental trees.

Table 1: Treatments details

Experimental Site	Experimental Orchard, Division of Fruit Science, SKUAST-K, Shalimar, Srinagar, J&K	
Crop	Apple	
Variety	Fuji Zhen Aztec	
Treatments	No. of Sampling dates (09)	
Period of Sampling	D_1	May 15
	D_2	June 1st
	D_3	June15th
	D_4	July 1st
	D_5	July 15th
	D_6	August 1st
	D_7	August 15th
	D_8	September 1st
	D_9	September15th
No. of replications		03
No. of plants/replications		25
Design of Experiment		RCBD

Sample Collection

Fruit samples were collected at each sampling date from each treatment. The samples were picked at an interval of 15 days from 15th of May to 15th of September for each replication of cultivar under study. Fruit samples were cleaned meticulously under tap water and with 0.2% liquid detergent after that fruits were again washed thoroughly with N/10 HCl and distilled water to eliminate metallic impurities.

Estimation of Sugars

Total sugars

25 gram of fruit pulp was taken and meticulously standardized by means of distilled water. Volume was prepared to 250 ml and 5 ml lead acetate was added to it. The precipitate was strained into a flask comprising of 5 ml potassium oxalate. Contents were shaken and again filtered, 100 ml of filtrate was taken in a 250 ml flask and to it was added a few drops of concentrated HCl. The filtrate was retained overnight to acquire hydrolysis of sugars completely. Leftover HCl was neutralized by saturated NaOH solution, with the help of phenolphthalein indicator. Boiling mixture (5 ml each Fehling's A and B solution) was titrated against a hydrolyzed aliquot in a burette containing methylene blue indicator to attain brick red color which is considered as the end point.

$$\text{Total sugars (\%)} = \frac{\text{Fehling factor x volume made up x 100}}{\text{Titre value x sample weight}}$$

Reducing sugars and Non-Reducing Sugars

For estimation of reducing sugars, un-hydrolyzed but lead free and clarified solution was titrated with bubbling solution containing 5 ml each of Fehling A and Fehling B using methylene blue as an indicator (A.O.A.C, 1984). End point was specified by brick red color and reducing sugars were calculated and expressed as per cent fresh weight of fruit pulp. Non-reducing sugar is determined by subtracting the reducing sugar from total sugar and multiplying the reminder with 0.95 factor.

Results and Discussion

The percentage of total sugars, reducing sugars and non-reducing sugars in developing fruits are presented in Table 2 and Fig.1. Assessment of data regarding total sugars (%) cited in Table 2 revealed that Total Sugars (%) of apple fruits was significantly affected by sampling dates and rootstocks. TSS of fruits showed an increasing trend until harvest. Total Sugars was documented to be high on last date of sampling i.e. D_9 (10.49%) and low on Ist date of sampling i.e. D_1 (3.42%). The data reveal that the percentage of both reducing sugars and non-reducing sugars increased from about 1st date of sampling (D_1) until last date of sampling (D_9). Seasonal variation regarding changes in Reducing Sugar and Non-Reducing Sugar content of apple fruits presented in Table 2 revealed that both types of sugars increased rapidly during early growth period until peak cell expansion and a gradual increase thereafter. While as maximum increment was recorded from July 15 to August 1 (D_5 to D_6). The maximum reducing sugar content in fruits was recorded on last date of sampling (D_9). Further the reducing sugar content in the developing fruits of apple started to increase from 3.24 per cent on May 15 (D_1) to 8.37 per cent on last date of sampling (D_9) corresponding to September 15 with rapid rate of increment from July 15 to August 1. Similar results were recorded for changes in non-reducing sugar content in the fruits of apple cv. Fuji Zehn Aztec with a maximum of 2.12 per cent on D_9; September 15 (last date of sampling) and minimum of 0.18 on D_1; May 15 (1st date of sampling).

The sugar content of fruits started to be detected from 15-20 days after fruit set. The presence of small quantity of sugars was observed at 30 DAFB corresponding to first date of sampling i.e. May 15/D_1. The rate of increase of sugars was maximum between July 15 to August 1 (D_5 to D_6). Thereafter

the rate of increase declined. However the sugars continued to accumulate till harvest. The increase in sugar content of fruits might be due to conversion of polysaccharides in to sugars during growth and development. The present results are supported by the findings of Paralkar *et al*., (1987) [11] in sapota fruits, Dutta and Dhua (2004) [8] in mango fruits and Aly *et al*., (2013) [2] in guava fruits. Similarly, the tendency of increment in non-reducing sugar during growth and development might be due to availability of starch to hydrolyze in to sugars. The findings are in agreement with Paralkar *et al*., (1987) [11] who reported continuous increasing trend in non-reducing sugar content of sapota. The results of present study are also in agreement with those reported by Aly *et al*., (2013) [2] in guava and Kumar and Deen (2015) [10] in bael fruits.

Table 2: Seasonal accumulation of Total Sugars (%), Reducing sugars (%) and Non-Reducing sugars (%) in developing fruits of apple Cv. Fuji Zehn Aztec during Fruit Development

Year/Treatments	Total Sugars			Reducing Sugars			Non-Reducing Sugars		
	2018	2019	Pooled	2018	2019	Pooled	2018	2019	Pooled
May15/D_1	3.41	3.43	3.42	3.23	3.24	3.24	0.18	0.19	0.18
June 1/D_2	5.75	5.81	5.78	5.45	5.46	5.45	0.31	0.35	0.33
June 15/D_3	6.30	6.31	6.31	5.77	5.78	5.77	0.53	0.54	0.53
July 1/D_4	6.93	6.98	6.95	6.17	6.19	6.18	0.76	0.78	0.77
July 15/D_5	7.75	7.79	7.77	6.81	6.84	6.82	0.94	0.96	0.95
August 1/D_6	8.43	8.45	8.44	7.28	7.29	7.29	1.14	1.15	1.14
August 15/D_7	9.13	9.17	9.15	7.41	7.42	7.41	1.72	1.75	1.73
Sept. 1/D_8	9.97	9.97	9.97	7.94	7.95	7.95	2.02	2.03	2.02
Sept. 15/D_9	10.46	10.53	10.49	8.35	8.40	8.37	2.11	2.13	2.12
CD (P≤0.05)	0.039	0.051	0.031	0.037	0.042	0.027	0.031	0.032	0.021

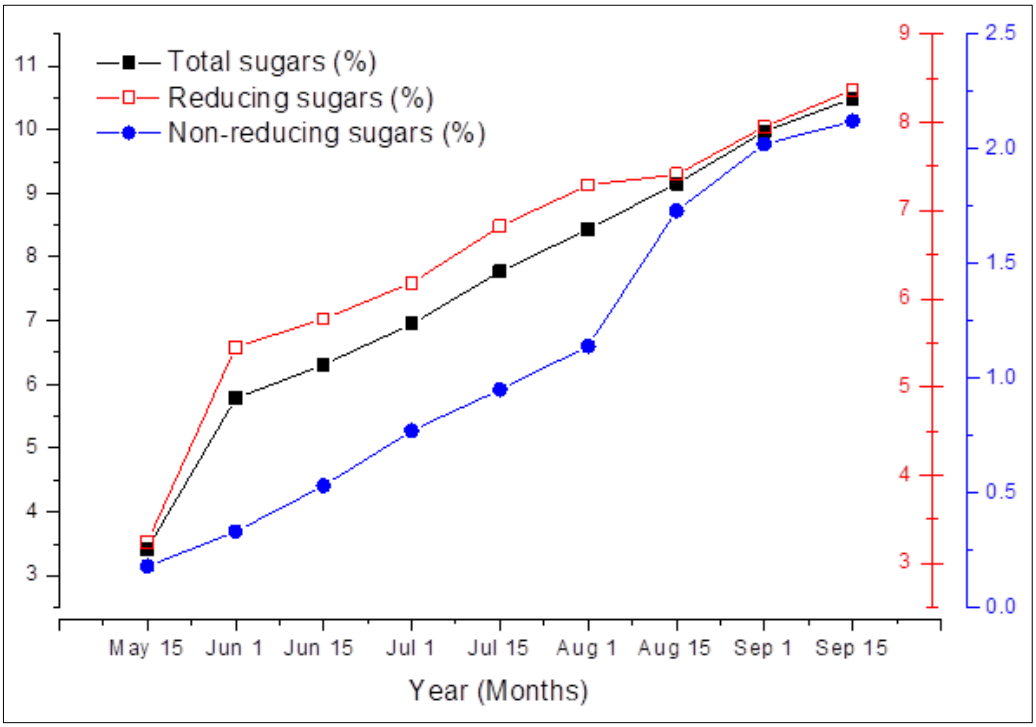

Fig 1: Seasonal accumulation of Total Sugars (%), reducing sugars (%) and Non-Reducing sugars (%) pooled over the two years in developing fruits of apple Cv. Fuji Zehn Aztec during Fruit Development

Conclusion

From the study it can be concluded that seasonal accumulation of sugars specified that sugar content increased throughout the season, undergoing slow and continuous increment till the end of fruit maturation signifying the trend of sugar accumulation along growing season and their effect on fruit quality. To freely convert translocation sugars quantitatively or qualitatively to other sugars will have a great impact on stimulating fruit development and improving fruit quality because sugars are the primary substrate of various fruit components.

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