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Evaluating Nutritional Quality and Shelf Life of Strawberry Genotypes under Field Condition

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ABSTRACT

The present study was conducted to assess the superior tropical strawberry genotypes in terms of their nutritional quality and shelf life. In this study, eight strawberry genotypes collected from different sources namely FA-006, FA-007, FA-008, FA-015, FA-016, FA-017, FA-022 and BARI Strawberry-1were selected. The study results implied that among eight strawberry genotypes, the maximum amount of reducing sugar (2.07g/100g) and non-reducing sugar (0.90g/100g) content were recorded in the genotype FA-017 and FA-008, respectively. The highest amount of ascorbic acid (29.45 mg/100g) and the highest amount of β-carotene (7.20 IU/100g) content were obtained from the genotype BARI Strawberry-1. The maximum amount of calcium (0.656 %), phosphorus (0.240 %) and potassium (1.580 %) content was recorded in the genotype FA-022 and the maximum sodium (0.166 mg) content was obtained from the genotype FA-007. Under room temperature, the highest shelf life (6.5 days) was recorded in the genotype FA-017. Regression analysis showed that total sugar content increased whereas β-carotene content decreased upon increasing storage duration. Collectively, our results provide a list of strawberry genotypes which could be released as promising varieties with higher nutrient content and storage capacity after large-scale trial.

Keywords: Sugar contents, Ascorbic acid, Mineral contents, Shelf life, Strawberry

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INTRODUCTION

Garden strawberry (*Fragaria* × *ananassa*) is one of the most popular and emerging fruit species in the world with its unique aroma and high nutrient contents (Giampieri et al., 2012). Several studies have shown that a diet rich in fruits and vegetables is often associated with a lower incidence of life threating pathologies, including obesity, infections, cardiovascular and neurologic diseases and cancer (Johnsen et al., 2003; Vauzour et al., 2010; Nasri et al., 2014). Strawberries have an important role among fruits because of their high levels of micronutrients and phytochemical constituents (Halvorsen et al., 2006; Afrin et al., 2016). Strawberry has a relevant nutritional quality (NQ) due to its high levels of micronutrients as vitamin C, folate and minerals as well as of phenolic constituents (Battino et al., 2009; Giampieri et al., 2012), that is attributed to huge biological potentialities in humans (Giampieri et al., 2012; Alvarez-Suarez et al., 2014).

Strawberries are the proper source of vitamin A, vitamin E and health flourishing flavonoid polyphenolic antioxidants such as lutein, zeaxanthin, and β-carotene in minor amounts. These compounds play a crucial role as protective scavengers against oxygen-derived free radicals and reactive oxygen species (ROS) that hugely contribute to aging and various disease processes (Giampieri et al., 2012). The nutritional value of strawberry is mainly due to the content of Vitamin C 100g

provide 58.8 mg or about 98% of RDI, which is also a powerful natural antioxidant (Sanz et al., 1999). It also contains 0.55 percent pectin, 90.6g water, 0.89g protein, 0.5g fat, 7.6g carbohydrate and 1.7g fiber, potassium, calcium, and phosphorus content being 7-12 percent (Jahan, 2010). Because of the potential health-promoting and disease-preventing effects, strawberry consumption has also been proposed as useful dietary components. More importantly, strawberries are economically and commercially significant and extensively consumed fresh or in processed forms, such as jams, juices, and jellies (Giampieri et al., 2012). For this reason, it is very urgent to identify the superior strawberry genotypes from the agronomic and nutritional points of view.

Great interest has developed in strawberries because of their extreme postharvest loss of fresh fruits, is one of the serious threats in the tropics, including Bangladesh. A considerable amount of strawberry is being spoiled in Bangladesh due to prevailing high temperature and humidity during the harvesting period. Though strawberries are extremely perishable fruits, therefore it is important to begin cooling within 1h of the harvest to avoid loss of quality and reduction in the amount of marketable fruit (Mangarj and Goswami, 2009). Temperature management is the single most important factor in minimizing strawberry deterioration and maximizing postharvest life. Therefore, the present study was undertaken to screen out the superior strawberry genotypes in terms of their nutritional quality and storage capacity of fruits.

MATERIALS AND METHOD

This study was conducted in the research field and laboratory of the Department of Horticulture, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during the period from March to July 2015. Seedlings were planted on 20 November 2014 in the research field of the Department of Horticulture. The soil of the experimental site was Clay loam in texture having a pH of 6.2. The field experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. In this study, eight genotypes (FA-006, FA-007, FA-008, FA-015, FA-016, FA-017, FA-022 and BARI SB-1) were selected and their details information was described by Akter et al. (2017). The genotypes were treated as treatments. Each block consisted of 8 plots and the dimension of each plot was 1m × 2.0m. The total number of the plot was 24. For all the plots, all necessary cultural practices and plant protection measures were followed uniformly. At ripening stage, fruits were harvested by hand picking when a three-fourths portion of the fruit skin attained red color at an interval of 3 to 4 days and handled very carefully. Harvesting was done in the morning when the weather is still cool. After harvest, strawberries were taken to the laboratory for analyzing the following parameters.

Estimation of Ascorbic acid

The ascorbic acid content was determined as per the procedure described by Pleshkov (1976). For the estimation of free ascorbic acid, 10 ml of prepared extract was taken in a conical flask. Five ml 5% KI, 2 ml of 2% starch solution, 2 ml of glacial acetic acid was added to the extract. Finally, it was titrated with 0.001N KIO_3 solution. Free ascorbic acid was quantified using the following formula:

$$\text{Ascorbic acid content (mg/100g)} = \frac{TFV}{vW} \times 100$$

Where,
T = Titrated volume of KIO_3 (ml)
F = 0.088 mg of ascorbic acid per ml of 0.001N KIO_3
V = Total volume of sample extracted (ml)
v = Volume of the extract (ml) taken for titration
W = Weight of the sample taken

Estimation of β-Carotene

One gram of sample was crushed and mixed thoroughly with 10 ml acetone: hexane (4:6) solution. This sample was centrifuged and optical density of the supernatant was measured by a spectrophotometer (Model no. 200-20, Hitachi, Japan) at 663 ηm, 645ηm, 505 ηm and 453 ηm. Calculation was done using the formula;

$$\beta\text{-Carotene (mg/100g)} = 0.216\,(OD_{663}) + 0.452\,(OD_{453}) - 1.22\,(OD_{645}) - 0.304\,(OD_{505})$$

Where OD indicates optical density (Nagata et al., 1992).

Estimation of reducing, total and non-reducing sugar

Reducing, total and non-reducing sugars were estimated using the procedure described by Somogyi (1952) using Bertrand A, B and C solutions. 10 ml each of Bertrand A (40g $CuSO_4$. $5H_2O$ dissolved in water and diluted to 1 litter) and Bertrand B (200g of sodium-potassium triturate and 150g of NaOH dissolved in water and diluted to 1 liter) solutions were added to five ml of sample solution. The conical flask was placed in a hot plate (sand bath) and boiled for three minutes and kept overnight for cooling. The supernatant was decanted and discarded very carefully by keeping precipitation. The precipitation was washed repeatedly until a blue color was present. 10 ml of 32 Bertrand C [50g Fe_2 $(S04)_3$ and 115 ml of conc. H_2SO_4 was added and diluted to 1 liter] was added to dissolve the precipitation (Cu_2O). Finally, the solution was titrated with a 0.4 percent $KMnO_4$ solution. This was repeated thrice and reducing sugar (g/100g) was calculated. Reducing sugar was calculated comparing tabulated values. Before calculation of reducing sugar, a factor of 0.4 percent $KMnO_4$ was determined. 5 ml of the extract solution was taken in a 100 ml conical flask and 2-3 drops of 4N HCl was added to it. Then the flask was

boiled for three minutes on a hot plate for hydrolysis. After cooling, the extract was neutralized with 1N NaOH to remove HCl and made up to the mark with water. 10 ml of the neutralized extract was taken into a 50 ml conical flask and 10 ml of both Bertrand A and Bertrand B solutions were added, following same procedure as mentioned in reducing sugar. The non-reducing sugar was calculated by deduction of reducing sugar from total sugar.

Determination of calcium, sodium, potassium and phosphorus contents

Calcium

Dried plant materials were digested with concentrated HNO_3 and $HClO_4$ mixture as described by Piper (1966) for determination of total calcium content. Atomic Absorption Spectrophotometer. Model no. 170-30, Hitachi, Japan was calibrated with a standard solution of Ca and a calibration curve was prepared by the series of standard solution. AAS readings of each standard solutions and soil sample extracts were recorded at a wavelength of 422.8 ηm for Ca. Total calcium content was calculated using the formula:

$$\text{Total Ca (\%)} = (S - B) \times (1000\text{ml} / 10\text{ml}) \times (50\text{ml} / 0.5\text{g}) \times 1/10^4$$

Where,
S = Sample absorbance
B = Blank absorbance

Sodium

Oven-dried samples of strawberry were grounded to powder for the determination of sodium. 1 mg of sample was taken into a dry polystyrene bottle rinsed with 25 ml 1N HCl from an automatic dispensing burette. It was allowed to stand for 24 h, shaken briefly and filtered through Whatman No. 1 filter paper. One ml aliquot was pipetted and was taken into a vial graduated at 40 ml, diluted to 40 ml with 1N HCl. Then Na reading was taken by EKO flame Photometer, Model FP-3B at different wavelengths. Finally, the amount of Na was calculated in percentage of two different standard curves.

Phosphorus

Dried plant materials were digested with concentrated HNO_3 and $HClO_4$ mixture as described by Piper (1966) for determination of total phosphorus content. Digestion procedure was the same as described in the case of total calcium. Determination by the Vanadomolybdate colorimetric method: Total phosphorous contained in the plant extract was determined by the Vanadomolybdate yellow color method as described by Jackson (1973). Total P content was calculated using the formula:

$$\text{Total P (\%)} = (S - B) \times (1000\text{ ml} / 10\text{ml}) \times (50\text{ml} / 0.5\text{g}) \times 1/10^4$$

Where,
S = Sample absorbance
B = Blank absorbance

Potassium

Dried plant materials were digested with concentrated HNO_3 and $HClO_4$ mixture as described by Piper (1966) for determination of total potassium content. Atomic Absorption Spectrophotometer. Model no. 170-30, Hitachi, Japan was calibrated with a standard solution of K and calibration curve was prepared by the series of standard solution. AAS readings of each standard solutions and soil sample extracts were recorded at a wavelength of 766.5 ηm for K. Total K content was calculated by using the formula:

$$\text{Total K (\%)} = (S - B) \times (1000\text{ ml} / 10\text{ ml}) \times (50\text{ml} / 0.5\text{g}) \times 1/10^4$$

Where,
S = Sample absorbance
B = Blank absorbance

Data analysis

Data of nutritive values and shelf life were analyzed following RCB design using MSTAT-C program. The mean comparison was done according to the Duncan's Multiple Range Test (DMRT). The correlation analysis was performed using Microsoft Excel 2010.

RESULT AND DISCUSSIONS

The sugar content of strawberry genotypes

Significant variation was found in total sugar content among the genotypes (Table 1). The highest amount of total sugar (2.80g/100g) content was found in the genotype FA-008. The genotype FA-015 had the lowest (1.46g/100g) total sugar content. The variation in total sugar content might be due to climatic and genetic factors. This results corroborated with the previous findings which reported that total sugar content in different strawberry cultivars varied from 6.21g/100g to 7.60g/100g under field conditions (Skupien 2003; Zmuda et al., 2004; Chowhan et al., 2016).
The amount of reducing sugar content among the genotypes was statistically significant (Table 1). The highest content of reducing sugar (2.07g/100g) was found in the genotype FA-017 and the lowest reducing sugar content (1.31g/100g) was found in the genotype FA-015 which was statistically identical with the genotype FA-006 (1.3g/100g). Similarly, the nonreducing sugar content was statistically significant among the studied

Table 1. Sugar content of eight strawberry genotypes.

Genotypes	Total sugar (g/100g)	Reducing sugar (g/100g)	Non-reducing sugar (g/100g)
FA-006	1.86 e	1.35 de	0.50 bc
FA-007	1.92 d	1.63 c	0.31 d
FA-008	2.80 a	1.91 b	0.90 a
FA-015	1.46 h	1.31 e	0.15 e
FA-016	1.69 f	1.63 c	0.06 f
FA-017	2.54 b	2.07 a	0.47 c
FA-022	2.24 c	1.68 c	0.56 b
BARI SB-1	1.55 g	1.42 d	0.13 e
Level of significance	**	*	**
CV (%)	1.50	2.42	8.49

Means bearing different letter(s) in a column differ significantly by DMRT (n=3). ** Significant at 1% and * Significant at 5% level.

Table 2. Ascorbic acid and β-carotene content of freshly harvested strawberries.

Genotypes	Ascorbic acid (mg/100g)	β-carotene (IU/100g)
FA-006	18.04 d	4.69 bcde
FA-007	17.49 d	4.15 e
FA-008	18.13 d	4.42 de
FA-015	22.29 c	4.91 bcd
FA-016	17.46 d	5.12 b
FA-017	23.27 b	4.50 cde
FA-022	21.82 c	5.04 bc
BARI SB-1	29.45 a	7.20 a
Level of significance	**	*
CV (%)	2.21	6.43

Means bearing different letter(s) in a column differ significantly by DMRT (n=3). ** Significant at 1% and * Significant at 5% level.

genotypes (Table 1). The maximum amount of non reducing sugar (0.90g/100g) content was recorded in the genotype FA-008 and the minimum amount of non reducing sugar (0.06g/100g) content was recorded in the genotype FA-016. Findings from this study was in accordance with other findings in strawberry genotypes which narrated that reducing and nonreducing sugar content in different strawberry cultivars ranged from 3.38 to 6.17 and 1.61 to 2.31g/100g, respectively (Skupien 2003; Chowhan et al., 2016).

Ascorbic acid and β-Carotene content of freshly harvested strawberries

The variation in free ascorbic acid content among the genotypes was statistically significant (Table 2). It ranged between 17.46 and 29.45 mg/100g. The highest content of free ascorbic acid was recorded in the genotype BARI Strawberry-1 (29.45 mg/100g). The lowest free ascorbic acid content was recorded in the genotypes FA-016 (17.46 mg/100g) which were statistically identical in the genotypes FA-006 (18.04 mg/100g), FA-007 (17.49 mg/100g) and FA-008 (18.13 mg/100g). Few studies claimed that ascorbic acid content fluctuated from 15 to 60 mg among studied 23 strawberry cultivars (Zmuda et al., 2004; Chowhan et al., 2016).

Significant variations in the amount of β-Carotene content were found when different genotype effect was considered. It varied from 4.15 to 7.20 IU/100g (Table 2). The genotype BARI Strawberry-1 had the maximum

Table 3. Mineral content of eight strawberry genotypes.

Genotypes	Ca (%)	Na (%)	P (%)	K (%)
FA-006	0.436 b	0.050 bc	0.160 b	1.50 b
FA-007	0.333 c	0.166 a	0.150 bc	1.12 d
FA-008	0.343 c	0.100 b	0.113 bc	0.836 e
FA-015	0.233 d	0.050 bc	0.130 bc	0.836 e
FA-016	0.440 b	0.043 bc	0.130 bc	1.453 b
FA-017	0.300 c	0.030 c	0.130 bc	1.220 c
FA-022	0.656 a	0.080 bc	0.240 a	1.580 a
BARI SB-1	0.423 b	0.056 bc	0.093 c	1.207 c
Level of Significance	*	**	**	**
CV (%)	6.83	28.88	17.74	1.61

Means bearing different letter(s) in a column differ significantly by DMRT (n=3). ** Significant at 1% and * Significant at 5% level, respectively. Ca (calcium), Na (sodium) P (phosphorus) and K (potassium).

amount of β-Carotene (7.20 IU/100g) content followed by the genotype FA-016 (5.12). The genotype FA- 007 had the lowest amount of β-carotene (4.15 IU/100g) content which was statistically identical to the genotypes FA- 006, FA-008 and FA-017.

Mineral content of strawberry genotypes

Significant variation in calcium content was observed among the genotypes (Table 3). The highest (0.656%) calcium content was found in the genotype FA-022 followed by the genotypes FA-006 (0.436%), FA-016 (0.440%) and BARI Strawberry-1 (0.423%) which was statistically similar. The lowest (0.233%) calcium content was found in the genotype FA-016. Chowhan (2012) notified that the calcium content of strawberry genotypes ranges from 0.373% to 0.480% which agreed with the findings of the present study.

Differences in sodium content were statistically significant among the studied genotypes (Table 3). The genotype FA-007 had the highest (0.166 mg) sodium content. The lowest (0.030 mg) sodium content was found in the genotype FA-017 which was statistically similar to the genotypes FA-006, FA-015, FA-016, FA-022 and BARI Strawberry-1.

There was a significant variation in phosphorus content among all the genotypes (Table 3). It ranged between 0.093 and 0.240%. The maximum content of phosphorus was recorded in the genotype FA-022 (0.240%). The lowest content of phosphorus was recorded in the genotype BARI Strawberry-1 (0.093%) which was statistically identical with the genotypes FA-007, FA-008, FA-015, FA-016, and FA-017.

The potassium content was also significantly different among the genotypes (Table 3). The highest amount of potassium (1.580%) content was found in the genotype FA-022. The lowest amount of potassium (0.836%) content was found in the genotype FA-008 which was statistically identical to the genotype FA-015 (0.836%). Mineral content results for sodium, potassium and phosphorus are well fitted with the previous study demonstrated by Chowhan et al. (2016).

Shelf life under room temperature

The strawberry genotypes had a significant influence on the shelf life of strawberries (Figure 1). At room temperature, the genotype FA-017 had the longest (6.5 days) shelf life followed by the genotypes FA-022 (5.72 days) and FA-016 (5.04 days). The shortest shelf life (3.20 days) was obtained by the genotype FA-007 followed by the genotypes FA-015 (3.67 days) and BARI Strawberry-1 (3.19 days). This might be due to the inherent control of the genotypes. Shelf life was also greatly affected by various temperature treatments. Finding from this study was supported by Rahman and Ahmad (2010) which reported that under room temperature (RT) shelf life ranged from 1.4 to 3.5 days in different strawberry genotypes. It is well established that high-temperature decreases and low temperature increases the shelf life of fruits by reducing respiration, transpiration and metabolism (Silva et al., 2013).

The relationship between shelf life with total sugar and β-carotene content

A positive linear relationship was observed between shelf life (days) and total sugar (g/100g) content in strawberry (Figure 2). The equation was $y = 0.193x + 1.135$ and the value of the coefficient of determination ($R^2 = 0.231$) gave

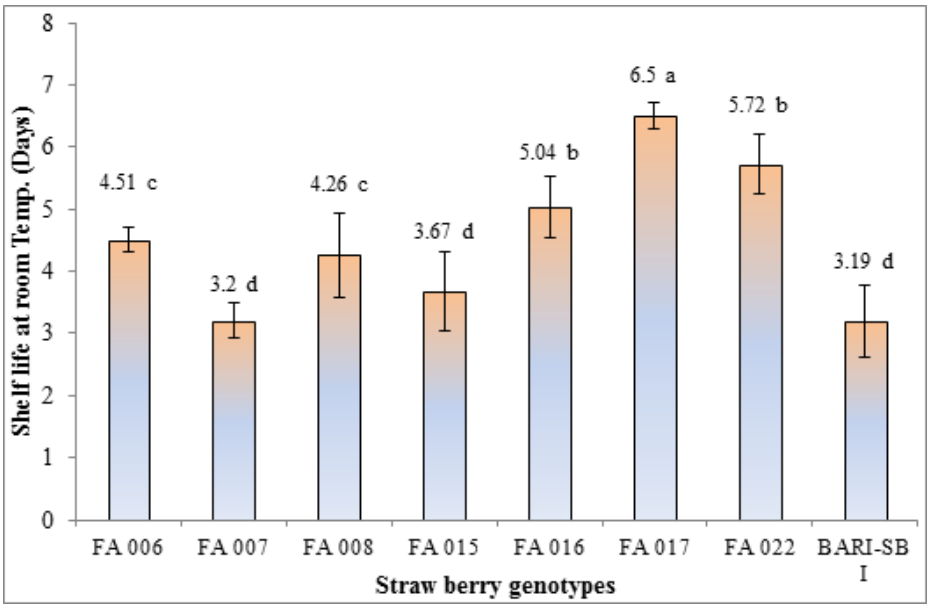

Figure 1. Shelf life (days) of eight strawberry genotypes.

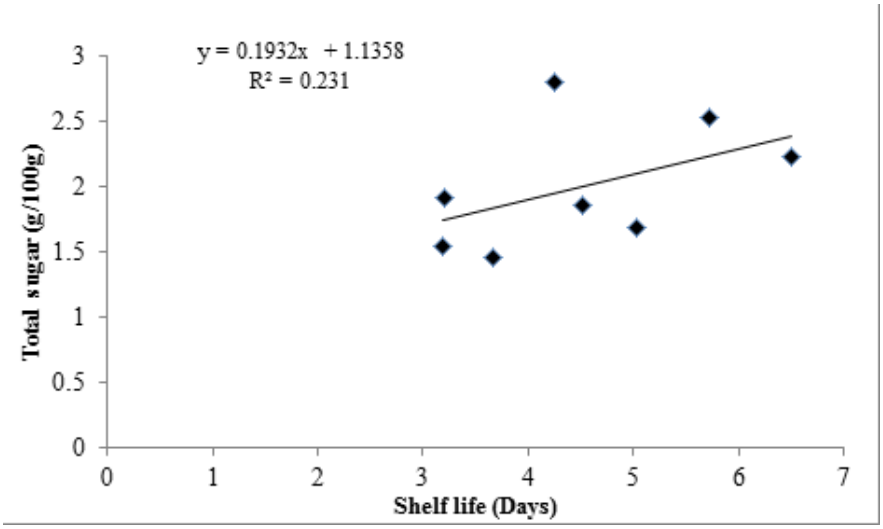

Figure 2. Relationship between shelf life (days) and total sugar (g/100g) content in strawberry.

a good fit and the fitted regression line had a significant regression coefficient, indicating sugar content will be increased with a significant manner with the increase days of storage. So, there is an indication that higher storage increases the total sugar content of strawberry fruit.

A negative linear relationship was observed between shelf life (days) and β-carotene (IU/100g) content in strawberry (Figure 3). The equation was y = -0.204x + 5.926 and the value of the coefficient of determination (R^2 = 0.066). This regression line coupled with significant regression coefficient β-carotene content decreased by a significant manner with the increase days of storage. So, it revealed that higher storage decreases the total β-carotene content of strawberry plants.

Conclusion

The strawberry genotypes showed significant variation in nutrient contents as well as the shelf life of fruits. In terms of nutritional status such as total sugar and a non-

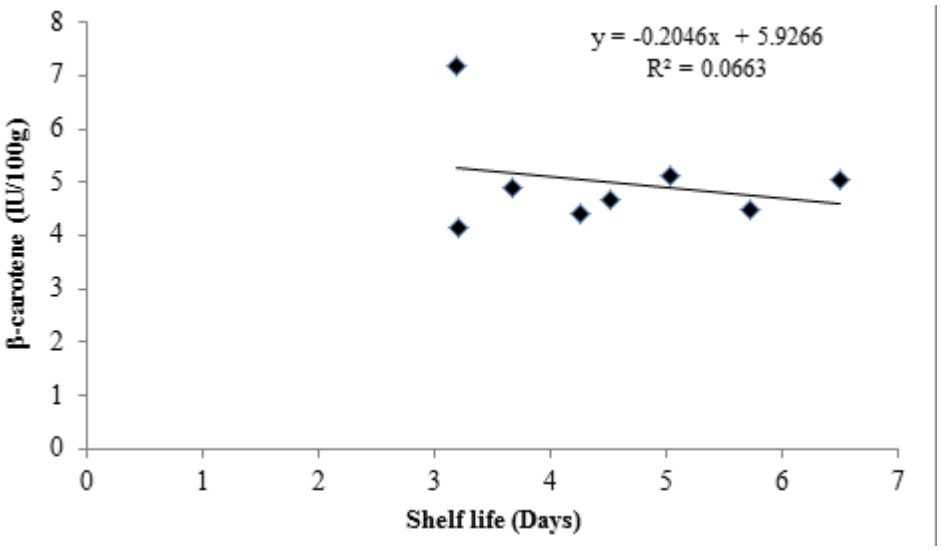

Figure 3. Relationship between shelf life (days) and β-carotene (IU/100g) content in Strawberry.

reducing sugar, genotype FA-008; and considering ascorbic acid and β-carotene content, genotype BARI Strawberry-1 was promising compared to other studied genotypes. Regarding mineral content such as Ca, Na, K and P,FA-022 genotype was more potential. On the basis of shelf life, genotype FA-017 showed the highest storage capacity than others. From our finding, we can also predict that upon increase in shelf life, total sugar content increased while β-carotene content decreased. Results from this study recommend few superior strawberry genotypes which could be released as nutrient-rich variety after multi-field trial.

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