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PHYSICAL AND CHEMICAL PROPERTIES OF SWEET ORANGE GENOTYPES AVAILABLE IN BANGLADESH

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ABSTRACT

Importance of fruits as valuable food resources, attention has been paid in recent years to study their physicochemical properties. Therefore, this investigation was undertaken to measure the physicochemical properties of the sweet orange genotype available in Bangladesh. A total of 8 genotypes including 3 released varieties (BAU Malta-1, BAU Malta-3, and BARI Malta-1) and 5 lines (CS Jain-001, CS Jain-002, CS Jain-003, CS Ram-001, and Variegated Malta) were included in this trial. Maximum average fruit weight (286.00 g), fruit size in terms of length (92.00 mm), and diameter (82.00 mm), mesocarp thickness (10.00 mm), and width of epicarp equatorial area (76.00 mm) was recorded from CS Jain-001 while the maximum number of segment (28.00), the diameter of fruit axis (23.66 mm), juice content (41.44%), titratable acidity (0.99%) and TSS: TA (33.73) was recorded from BAU Malta-3. TSS and juice pH was recorded maximum of 10.21% and 4.48, respectively in BAU Malta-1. Sugar content was found to be as follows, reducing sugar was the maximum in CS Jain-001 (3.50 %) while the highest total sugar (4.68%) was recorded in BAU Malta-1. Variegated Malta produced the maximum (48.45 mg/100 ml juice) ascorbic acid while CS Jain-001 contained maximum (8.35 mg/100 ml juice) ß-carotene. Therefore, considering fruit quality, BAU Malta-3, BARI Malta-1 can be used as fresh fruit. However, considering the fruit size, CS Jain-001 and CS Jain-002 could be used as breeding material to develop a new sweet orange variety with higher yield potential.

Keywords: Sweet orange, *Citrus sinensis*, physical, chemical, and nutritional properties

INTRODUCTION

Sweet orange (*Citrus sinensis* Osbeck) belongs to the Rutaceae family originated from south-east Asia and is the most widely used species of citrus fruits, but is used around the world as an excellent source of the body's immune system, Vitamin C, a strong natural antioxidant (Ibrahim & Yusuf, 2015). In Bangladesh, it is commonly known as Malta. So far, Bangladesh Agricultural Research Institute (BARI) has released two varieties (BARI Malta-1 & BARI Malta-2) and Bangladesh Agricultural University (BAU) has also developed three Malta varieties as BAU Malta-1, BAU Malta-2 & BAU Malta-3 and these varieties are getting popular day by day. It contains sufficient amount of folacine, calcium, potassium, thyamine, niacin, magnesium and different phytochemicals such as limonosides, synephrine, hesperidine flavonoids, polyphenols or pectin. These biologically active substances prevent arteriosclerosis, cancer, kidney stones, stomach ulcers, cholesterol and blood pressure, which contribute to human health (Etebu & Nwauzoma, 2014). Phytochemicals are nutritional and non nutritionally beneficial bioactive compounds (Patil *et al.*, 2009). Their adequate intake reduces chronic heart disease incidence, mortality and cancer (Aune *et al.*, 2017). Oranges are important fruit crops economically, with an annual production of around 89,28 million metric tonnes, world-wide from 4,63 million ha as of 2019 (FAO, 2020).

Sweet oranges are produced worldwide on a large scale and its demand is high due to fewer seeds in fruits. Several researchers have performed biochemical profiling of sweet orange cultivars and have identified increased levels of sugars and minerals including potassium, magnesium, calcium and phosphorous (De Moraes Barros *et al.*, 2012; Topuz *et al.*, 2005). Xu *et al.,* (2008) also recorded greater antioxidant capacities in oranges, recommending more suited for juice processing than mandarins, lemon, grapefruit and pummelo. Rootstock (Hussain *et al.*, 2013), cultivars (Bermejo *et al.*, 2011; Cano *et al.*, 2008), genetic factors (Dhuique-Mayer *et al.*, 2009), climate (Marsh *et al.*, 2000) and cultural activities (Lee & Kader, 2000) primarily affect the quality of fruit. Mostly, the people of Bangladesh consume fruit on a seasonal basis; however, papaya, guava and banana grown very limited scale around the year. Present consumption of fruits in Bangladesh is 82 g per day per person which is far below

the recommended dietary allowance of 200 g (World Bank, 2019). Although there are large numbers of fruit grown in Bangladesh, the availability period is confined from May to August. Sweet orange can play an important role in extending the availability period of fruits as it starts harvest after September.

The physicochemical properties of fresh fruits are main criteria for quality. The major physiochemical characteristics for fruit maturation are firmness, color of flesh and peel, total soluble solids content (SSC), titrable acidity (TA), and aromatic volatile substances (Ngamchuachit *et al.*, 2016). After bananas, citrus fruit is eaten in vast amounts worldwide, either as fresh, as juice, or as processed products such as marmalades, jams or paste (S. B. Hussain *et al.*, 2017). Fruit yield, quality, and composition are significantly affected by genetic and environmental factors in sweet orange. These include genotype, soil and climate and environmental factors such as solar radiation, temperature, season of cultivation, agricultural practices and conditions after harvest. In order to improve genotypical characters, a large genotypical variability is also required. Also, breeding programs must be designed to develop a high yield variety with better quality. For crop improvement programmes, physicochemical characterization of genotypes, including germplasm and commercial varieties, is relevant and facilitates the selection of genotypes of higher yield and superior quality for breeding programmes. In Bangladesh, numerous research work on physicochemical properties of fruits such as mango (*Mangifera indica*), papaya (*Carica papaya*), burmese grape (*Baccaurea ramiflora*), wood apple (*Limonia acidissima*), guava (*Psidium guajava*), jujube (*Ziziphus jujube*) and sapota (*Manilkara sapota*) has been reported by Ara *et al.,* (2015); Haque *et al.,* (2009) and Hossain *et al.,* (2016). Unfortunately, there is very few information available in Bangladesh about fruit physicochemical compositions of sweet orange genotype. In recent years, yield and quality improvement of fruit crops is a vital concern for agricultural production globally which is a big challenge in agriculture. Characterization is an important feature for documentation of the performance of the cultivars studied, and will then help to introduce, identify and improve existing variety thereby extend the supply of sweet orange during the lean season. This research was therefore aimed at examining and comparing the physical and chemical properties of sweet orange genotypes in Bangladesh in order to provide useful information for the best use of sweet orange cultivars in technology and processing.

MATERIALS AND METHODS

Plant material and growth condition

The investigation was carried out during the years of 2016-2017 on sweet orange grown and maintained in the Fruit Research Farm, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. Seven years old healthy tree of three sweet orange varieties viz., BARI Malta-1, BAU Malta-1, BAU Malta-3, and five lines viz., CS Jain-001, CS Jain-002, CS Jain-003, CS Ram-001, and Variegated Malta were selected for this study. This experiment was laid out in a Randomized Complete Block (RCB) design with three replications.

Fruit sampling

Randomly collected mature fruit samples of different sweet orange genotypes were subjected to the Post Harvest Technology Division laboratory, BARI for determining the physicochemical properties. For each fruit character, ten fruits were collected randomly and observations were recorded on each fruit separately.

Fruit physical attribute

Parameters like fruit length, fruit diameter, the thickness of mesocarp, the width of epicarp at the equatorial area, and diameter of fruit axis were recorded using Digital Vernier Calipers where the number of segments was counted manually. The juice was collected from pulp and weighted by an electric balance. Then juice (%) was calculated using equation 1.

$$\text{Juice content (\%)} = \frac{\text{Weight of juice (g)}}{\text{The average weight of fruit (g)}} \times 100$$

----Equation 1

Fruit chemical attribute

Immediately after the collection of physical parameters, the pulp was rapidly separated, squeezed and filtered the juice to determine the fruit quality, including total soluble solid (TSS), pH of juice, titratable acidity (TA), sugar, β-carotene and ascorbic acid. The total soluble solids content of fully mature fruits was recorded with a hand-held refractometer (Atago Co. Ltd., Japan). The pH of the juice was estimated by a hand pH meter.

TSS and juice pH measurement

A handheld refractometer (Atago Co. Ltd., Japan) was used to record total soluble solid content of fully mature fruit. The pH of the juice was estimated by a hand pH meter.

Titratable acidity (TA)

The titratable sweet orange pulp acidity was determined by the method of Rangana (1979). Ten milliliters juice extracted from pulp was taken in a 250 ml conical flask. Two or three drops of the indicator phenolphtalein were applied to the flask and vigorously shaken. It was then

titrated instantly with 0.1 N NaOH solutions from a burette till a stable pink color appeared. From the burette reading, the volume of NaOH solution for titration was registered. The titration was done in triplicate percent titratable acidity was calculated by using the following formula:

$$\% \text{ Titratable acidity} = \frac{T \times N \times V_1 \times E}{W \times V_2 \times 1000}$$

----Equation 2

Here,

T: Titre
N: Normality of NaOH
V_1: Volume made up
E: Equivalent weight of acid
V_2: Volume of extract
W: Weight of sample

Measurement of sugar

Determination of Fehling's factor

Sugar content was determined by the method ascribed by (Rangana, 1979). The Fehling solution was standardized by combining the same quantity of Fehling's solution A and Fehling's solution B in the beaker then 10 ml of this mix solution was taken into a 250 ml conical flask and 25 ml double distilled water was added to it. On a hot plate, the conical flask containing the mixer solution was heated and three drops of a solution for methylene blue indicators were added. Standard sugar solution was used to titrate the mix solution. Decolorization of the indicator showed the endpoint.. Fehling's factor was calculated by using the following formula:

$$\text{Fehling's Factor} = \frac{\text{Titre} \times 2.5}{1000}$$

Sample preparedness

About 50 g of fresh sweet orange pulp was blended along with distilled water in a blender. The merged materials were then filtered and transferred to a 100 mL volumetric container, and distilled water provided the volume. One hundred milliliters of the filtrate was taken in a 250 ml volumetric flask. Approximately 5 ml of 45% neutral lead acetate solution was added to it and shaken and after 10 minutes, 5 ml of 22% potassium oxalate solution was added to the flask and the volume was made up to the mark with distilled water.

Determination of reducing sugar

In a conical flask of 250 ml, 10 ml Fehling's solution mix was added with 25 ml distilled water. A burette was used for 25 milliliters of purified sweet orange juice. At boiling, three drops of the methylene blue indicator were applied to the flask that contained Fehling's solution mix. The endpoint was measured by decolorization of the indicator from titration with fruit pulp solution.

The reducing sugar (%) was calculated as stated below.

$$\% \text{ Reducing sugar} = \frac{\text{Fehling's factor} \times \text{Dillution}}{\text{Titer} \times \text{Weight of the sample}} \times 100$$

----Equation 3

Measurement of total sugar

A 250 ml conical flask was taken with 50 milliliters of purified filtrate. Approximately 50 ml of distilled water and 5 g of citric acid was added to it and heated until boiling. After cooling, the solution has been transferred to a volumetric flask of 250 ml and neutralized by 1N NaOH using a phenolphthalein indicator. The volume was made up to the mark with distilled water. The Fehling's solution mix was then titrated using the same technique as for the reducing sugar previously described. Decolorization of the indicator showed the endpoint.

$$\% \text{ Total sugar} = \frac{\text{Fehling's factor} \times \text{Dillution}}{\text{Titre} \times \text{Weight of sample}} \times 100$$

----Equation 4

Extraction and quantification of total ascorbic acid

The total ascorbic acid was extracted and quantified following Shrestha & Bhattarai (2016), with some modifications. Orange juice were combined with equal volume of 3% metaphosphoric acid and filtered through cotton. About 2 ml of metaphosphoric acid was mix with 5 ml of filtrate in a 50 ml conical flasks, titrated with Indophenols dye and Ascorbic acid concentrations were determined by the following formula

$$\text{Vitamin C (mg } 100g^{-1}) = \frac{T \times D \times V_1}{V_2 \times W} \times 100$$

----Equation 5

Where,

T: Titre
D: Dye factor
V_1: Volume made up
V_2: Aliquot of extract taken for estimation and
W: Weight of sample taken for estimation

β-carotene determination
The content of β-carotene was calculated with certain modifications using the techniques mentioned in Nagata *et al.,* (2007). One milliliter of sweet orange juice mixed thoroughly with a 10 ml acetone: hexane (4:6) solution. The optical density of centrifuged specimen was measured

with spectrophotometer (Model 200-20, Hitachi, Japan) at 663 nm, 645 nm, 505 nm and 453 nm wave length. Equation 6 was used to quantify β-carotene content and expressed as mg 100g-1.

ß-Carotene =
$0.216(OD_{663}) + 0.452(OD_{453}) -1.22(OD_{645}) - 304(OD_{505})$

----Equation 6

Where, bold figure displays the optical density

Statistical analysis

All collected data were analyzed by one-way analysis of variance (ANOVA) using R software. LSD tests were performed to determine the significant ($P \leq 0.05$) differences among means. To determine the differences between genotypes, the coefficient of differences (CV) were calculated diving pertinent standard deviations by means and expressed as percentage.

RESULTS AND DISCUSSION

Physical characteristics of eight selected sweet orange genotypes

The Fruit physical properties of the eight sweet orange genotypes were shown in Table 1. As seen in Table 1, the physical properties of the sweet orange genotypes were found to be statistically significant at 5% level of probability. The fruit weight of both the CS Jain-001 and CS Jain-002 were statistically at par with each other with the highest value of 286.00 g and 282.00 g, respectively but these two genotypes significantly differed from the other genotypes. The fruit weight was the lowest (117.66 g) in Variegated Malta. However, CS Jain-001 and CS Jain-002 produced 145% and 140% higher fruit weight than Variegated Malta. These significant findings could be the results of the individual properties of sweet orange genotypes.

A statistically significant fruit diameter of 8 genotypes was found at 5% probability level, ranging from 63.66 mm to 92.00 mm; (Table 1). The CS Jain-001 genotype was the highest diameter (92.00 mm) of the fruit among the genotype, whereas the lowest diameter of the fruit (63.66 mm) was observed at Variegated Malta genotypes. The similar result was discovered by Pun & Thakur (2018) as the fruit diameter was found between 52.44 and 92.80 mm among sweet orange genotypes. The fruit length of both CS Jain-001 and CS Jain-002 was significantly greatest (82.00 mm) than the length of the other genotypes varying from 56.66 to 82.00 mm while BARI Malta-1 showed the shortest (56.66 mm) fruit. Mesocarp thickness of sweet orange genotypes also differed significantly where the highest (10.00 mm) mesocarp thickness was recorded from CS Jain-001 and BAU Malta-3 followed by CS Jain-002 (9.00 mm) and CS Jain-003, whereas, the lowest (3.66 mm) from variegated Malta. The width of the epicarp equatorial area was found to differ significantly with the greatest (76.00 mm) from CS Jain-001 and BAU Malta-3 as against the lowest (46.00 mm) value was recorded from Variegated Malta. The number of segments varied from

Table 1. Physical characteristics of eight selected sweet orange genotypes

Genotypes	FW (g)	FD (mm)	FL (mm)	TM (mm)	WE (mm)	SN (no.)	DA (mm)
CS Jain-001	286.00a	92.00a	82.00a	10.00a	76.00a	27.33a	23.00ab
CS Jain-002	282.00a	89.00b	82.00a	9.00ab	66.00b	23.00b	22.00b-d
CS Jain-003	182.00e	65.00g	60.00d	8.00bc	56.00d	18.00e	23.00ab
CS Ram-001	201.33c	76.66d	63.00c	7.00c	66.00b	22.00bc	21.00c-e
Variegated Malta	117.66g	63.66h	62.00cd	3.66d	46.00e	18.00e	20.66de
BAU Malta-1	158.00f	68.16f	66.66b	7.00c	61.00c	20.00d	20.00e
BAU Malta-3	248.00b	87.66c	80.00a	10.00a	76.00a	28.00a	23.66a
BARI Malta-1	188.00d	73.66e	56.66e	5.00d	56.00d	21.00cd	22.33a-c
CV	28.71	14.68	15.31	30.61	16.42	17.23	5.87
LSD (0.05%)	4.04	1.297	2.07	1.75	0.61	1.59	1.54

FW: Fruit weight, FD: Fruit diameter, FL: Fruit length, TM: Thickness of mesocarp, WE: Width of epicarp equatorial area, SN: Number of segment fruit-1 and DA: Diameter of fruit axis.

Table 2. Chemical characteristics of eight selected sweet orange genotypes

Genotype	% Juice	TSS (%)	pH	Titratable acidity (%)	TSS: TA
CS Jain-001	38.33b	7.53e	3.01e	0.99a	7.63f
CS Jain-002	37.50c	7.83cd	4.12b	0.36cd	21.75c
CS Jain-003	34.30e	7.73de	3.21e	0.63b	12.42e
CS Ram-001	33.62fg	6.84f	3.57d	0.32de	21.33cd
Variegated Malta	36.43d	7.70de	3.96bc	0.38c	18.97d
BAU Malta-1	33.42g	10.21a	4.48a	0.37cd	27.59b
BAU Malta-3	41.44a	8.00c	4.45a	0.27e	33.73a
BARI Malta-1	33.74f	9.20b	3.78cd	0.39c	23.55c
CV	7.95	13.10	14.10	51.20	38.66
LSD	0.31	0.25	0.26	0.46	2.59

18 in variegated Malta to 28 in BAU Malta-3. However, the range of segments in this study was higher than the recorded segments (Baswal *et al.*, 2017), possibly due to the difference in the genotype, climate and geography. In terms of fruit axis diameter, the highest (23.66 mm) diameter was observed in BAU Malta-3 compared to the lowest (20.00 mm) from BAU Malta-1.

Chemical properties of eight selected sweet orange genotypes

The data on chemical properties like juice percentage, TSS (% Brix), juice pH, % titratable acidity, ascorbic acid (Vitamin C), β-carotene content, reducing sugar (%), and total sugar content of fruits are presented in Table 2 and Table 3.

Significant differences ($p \leq 0.05$) among the sweet orange genotypes were detected in all measured parameters under this study. The juice yield (%) is extremely significant in the juice industries and fresh consumption and can also increase fruit value (Pareek, 2016), as a result of this desirable attribute, which positively affects industrialized product yields and fresh fruit consumer satisfaction.. The values of juice yield varied largely among sweet orange genotypes, where BAU Malta-3 achieved the highest juice yield (41.44%) followed by BARI Malta-1 (33.74%), and BAU Malta-1 had the lowest juice yield (33.42%) among the released variety of sweet orange. Moreover, CS Jain-001 and CS Jain-002 were observed to have a higher juice yield of 38.33% and 37.50% among lines, respectively. In this analysis, the percentage of juice observed between 33.42 to 41.44 percent which was close to the range mentioned by Chahal & Gill (2015). TSS is an important indicator of the fruit's sugar level since sugars comprise about 85 percent of the citrus fruit soluble solids (Wardowski *et al.*, 1979), which is a very useful index of fruit quality and a appropriate criterion for harvest decision (Lado *et al.*, 2014). Citrus cropping periods is associated to the time of onset of quick physiological changes, mainly increases in soluble solids substance and declines in acid during the development of citrus fruits (Wardowski *et al.*, 2006). The total soluble solids (TSS) were varied significantly among the released variety and lines studied. The highest TSS (10.21%) was recorded from the genotype BAU Malta-1 which is statistically at par with BARI Malta-1 (9.20%) and the lowest (6.84%) was in variegated Malta. This was coherent with earlier reports by Baswal *et al.,* (2017), who found the same range of TSS among different sweet orange genotypes in Punjab.

Juice acidity is a trait often not taken into consideration, but it is becoming a vital attribute in fruit quality definition. The fruit taste is a balance between acids, sugars, and volatile compounds and the low acidity is the desirable trait for fresh fruit consumption (Chahidi *et al.*, 2007). Wide variations of pH and titratable acidity (14.10 and 51.20% Co-efficient of variation values, respectively) were noticed among the studied sweet orange genotypes. Juice pH was diverse from 3.01 (CS Jain-001) to 4.48 (BAU Malta-1) while the titratable acidity ranged from 0.27 (BAU Malta-3) to 0.99% of citric acid (CS Jain-001), which was similar to the results of De Moraes Barros *et al.,* (2012). Accordingly, the variations in TSS and TA therefore resulted in broad TSS: TA differences where BAU Malta-3 had the highest value of TSS: TA (33.73) and CS Jain-001 (7.63) had the lowest value. It is generally recognized that TSS: TA relative amount has

Table 3. Chemical characteristics of eight selected sweet orange genotypes

Genotype	Ascorbic acid (mg/100 ml juice)	ß-carotene (mg/100 ml)	Reducing sugar (%)	Total sugar (%)
CS Jain- 001	35.65 b	8.35 a	3.50 a	4.14 bc
CS Jain-002	44.86 a	7.78 ab	3.15 b	4.00 c
CS Jain-003	36.83 b	7.32 bc	2.94 c	3.70 d
CS Ram-001	46.81 a	8.00 ab	2.33 d	3.51 e
Variegated Malta	48.45 a	8.21 a	2.36 d	3.58 de
BAU Malta-1	33.39 b	5.48 d	3.17 b	4.68 a
BAU Malta-3	36.93 b	6.61 c	2.94 c	4.25 b
BARI Malta-1	47.85 a	8.05 ab	2.30 d	3.54 de
CV	15.03	13.14	16.00	10.62
LSD	3.89	0.88	0.19	0.17

been considered a more reliable internal quality index worldwide for commercialization than peel coloration in sweet orange, since important changes occur in external color development (Lado *et al.*, 2014). In general, a TSS: TA ratio of at least 6 or higher is acceptable for commercial marketability; however, important differences may exist depending on the citrus species and varieties, as well as also on the growing regions (Department of Agriculture and Food, 2020). In this study, all the sweet orange genotypes fell above the minimum value of the TSS: TA ratio. Thus, it can be presumed that the selected genotypes had superior quality and acceptability.

The content of ascorbic acid in fruits and vegetables can be influenced by various factors such as genotypic differences, climatic conditions, and cultural practices (Lee & Kader, 2000). Significant genotypic differences were observed concerning ascorbic acid content (Table 3). Ascorbic acid has a significant role in the reduction of free radicals, and is a water-soluble antioxidant (Kaur *et al.*, 2013). Citrus is well known to be a nutrient source of ascorbic acid. Of the sweet orange ascorbic acid analyzed in this study, ascorbic acid content differed from 33.39 to 47.85 mg/100 ml juice and 35.65 to 48.45 mg/100 ml in the release variety and germplasm lines, respectively. Among the released variety, mean ascorbic acid content was the highest in BARI Malta-1 (47.85 mg/100 ml) than the lowest (33.39 mg/ml) in BAU Malta-1; however, in the germplasm lines, the highest (48.45 mg/100 ml) ascorbic acid content was observed in Variegated Malta than the lowest (35.65 mg/100 ml) in CS Jain-001. Most genotypes had ascorbic acid levels comparable to De Moraes Barros *et al.,* (2012); Proteggente *et al.,* (2003). However, the amount was lower than the content of the ascorbic acid in the experiment and genotype lines recorded by Duzzioni *et al.,* (2009), which might be as of differences in the environmental conditions and genotypes.

β-carotene also demonstrated wide genotypic variation among various lines and released variety varying between 5.48 to 8.05 and 7.32 to 8.35 respectively. The highest (8.35 mg/100g) carotene was recorded from CS Jain-001 followed by Variegated Malta (8.21 mg/100g), BARI Malta-1 (8.05 mg/100g), CS Ram-001 (8.00 mg/100g), and CS Jain-002 (7.78 mg/100g) which were statistically identical each other. The difference in carotene content in evaluated genotypes was similar to the information of Bhandari *et al.,* (2016), who explained that both genetic and environmental factor greatly affect the functional quality and composition of beneficial compound in fruit.
Sugars plays a major role in the flavor characteristics and commercial consideration of sweet orange fruit quality and increase in the sugar component makes the fruit much better (Riaz *et al.*, 2015). As shown in Table 3, reducing sugar was found to differ significantly among the studied genotypes. Reducing sugar content varied from 3.50 (CS Rai-001) to 2.30% (BARI Malta-1). Among commercial genotypes, BAU Malta-1 exhibited higher reducing sugar content than other commercial genotypes, while in the germplasm lines, CS Jain-001 and CS Jain-002 showed statistically higher reducing sugar than other genotypes. The concentration of total sugar was found statistically significant ($P \leq 0.05$) in Table 3. Total sugar concentration in BAU Malta-1 (4.68%) was the highest followed by BAU Malta-3 (4.25%), while the lowest was in CS Ram-001 (3.51%). Such variation may be due to genotype variations, growing environment, and analysis techniques.

CONCLUSION

There were extensive genotypic differences among commercial cultivars and germplasm lines studied, based on their physical and chemical attributes. Significant genotypic differences were found between the commercial cultivars and the lines tested in terms of physical and chemical attributes. The CS Jain-001, CS Jain-002 germplasm showed a higher weight, length and diameter of fruit than released variety; therefore, plant breeders could exploit the results of the present study to develop special, better yielded sweet orange cultivars that meet market demand. These results also showed that among the varieties; BARI Malta-1 and BAU Malta-1 showed superior quality in terms of TSS, Sugar, vitamin C, β-carotene, ascorbic acid than all other genotypes which could be used for fresh consumption as well as commercialization.

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