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Physico-chemical characterization of kiwifruit grown in different parts of India

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Abstract

The present study was carried out to investigate the physico-chemical parameters of five cultivars of Kiwifruit (Abbott, Allison, Bruno, Hayward and Monty) grown in different states of India (Sikkim, Nagaland, Arunachal Pradesh and Himachal Pradesh). Physico-chemical analyses such as fruit weight, fruit diameter, fruit length, fruit volume, fruit density, fuzziness, TSS, titratable acidity, ascorbic acid, reducing sugar, non-reducing sugar and total sugar were determined. The physico-chemical properties of the fruits showed significant variations amongst cultivars and the locations of cultivation. Fruit weight was in the range of 42.38g in cv. Abbot grown in Himachal Pradesh to 95.84 g in cv. Bruno grown in Arunachal Pradesh. Fruit diameter was as high as 168 mm in cv. Hayward grown in Sikkim. Fruit length of 112 mm was observed as the highest in cv. Bruno grown in Arunachal Pradesh. TSS was in the range of 11.16 ^{o}B in cv. Monty collected from Himachal Pradesh to 17.03 ^{o}B in cv. Allison collected from Arunachal Pradesh. The variations in ascorbic were in the range of 80 mg (cv. Abott grown in Himachal Pradesh) to 112.26 mg/100g (cv. Bruno grown in Himachal Pradesh). All the cultivars under study had a narrow range of total sugar (11.26%- 12.99 %). Overall, the results revealed an appreciable quality of fruits grown in North East India at par with the commercially known kiwi-growing state of Himachal Pradesh. Almost all the physico-chemical parameters taken during the present studies were found to be at par with reported data of marketable fruits from different parts of the world, which reveals the standard quality of kiwifruits grown in India. More studies can be undertaken to establish the physico-chemical markers to identify the source of fruit.

Key word: Kiwifruit, physico-chemical analysis, cultivars, geographical variation

Introduction

Kiwifruit (*Actinidia deliciosa*) is highly nutritive, rich in vitamins and sugars and has a refreshing, delicate flavour, a pleasing aroma with high medicinal value. *Actinidia* fruit has a high content of vitamin C (Okamoto and Goto, 2005) and is increasingly popular not only due to *its* taste but also due to its benefits for health (Latocha *et al.*, 2017). Some studies have shown that the extracts of kiwifruit exhibit cell protection against oxidative DNA damage *in vitro* (Collins *et al.*, 2001) and inhibit cancer cell growth (Song, 1984) and are found to have a preventive effect against cardiovascular disease. Kiwifruits are used in traditional medicine for the treatment of various cancers especially lung, liver and mainly stomach cancer (Yang, 1981; Basnet *et al.*, 2016) due to their antioxidant activities.

In India, Kiwifruit after its introduction in the state of Himachal Pradesh in the year 1960, was grown commercially in the mid hills of Himachal Pradesh and Jammu and Kashmir in North West-Himalayan region for over 3-4 decades. The crop is fairly introduced to different states of North-East states of India (Jindal *et. al*., 2021), particularly Sikkim, Arunachal Pradesh and Nagaland. In Sikkim, it is gaining popularity and is being grown in the organic production system. The popularization of fruit production and increase in production not only depends on successful production but also on the quality of fruits to withstand the competitive market. The quality of the fruits is characterized by physical parameters (weight, shape, size, volume, colour, etc.) and biochemical constituents.

There have been no comprehensive studies on the chemical parameters of kiwifruit taking into consideration the cultivars grown in different states. This study aims to address the research gap in quality assessment of the fruits in terms of physico-chemical parameters grown in Northeastern India vis-à-vis Himachal Pradesh to ascertain its consumer preference and commercial production. In this study, we hypothesized that the expression of unique physico-chemical traits may vary as per the geographical locations. It is highly imperative to assess the quality of the fruits grown in each region to understand the variations. It is even more important to study the quality traits especially when the crop is newly established or introduced to a new region.

Materials and methods

Fully matured fruit samples of select cultivars *viz*., Abbott, Allison, Bruno, Hayward and Monty were sampled from the orchard located in the state of Sikkim (Gangtok, 27° 20.1696' N 88° 36 .4216' E, Altitude 1509 m), Nagaland (Phek, 25° 41.17' N 94° 27.43' E, Altitude 1545m), Arunachal Pradesh (Ziro, 27°32.654' N, 93°49.43' E, 1562 m,) and Himachal Pradesh (Solan, 30° 54.1496' N 77° 5.2388' E, 1450 m). Fruits were randomly taken from the orchard from each location and samples were aggregated location-wise for further analysis.

Fruit weight was measured using an electronic weighing balance (Mettler Toledo) and expressed in gram (g). Fruit diameter and fruit length were measured using Vernier Calipers (Mitutoyo) and expressed in millimeters (mm). Fruit volume (expressed as cubic centimeters, cc) was determined by the water displacement

method. Fruit density was measured by the Weight/ Volume method and calculated as fruit weight per unit volume and expressed as g/cm^3).

For biochemical parameters, the peels of the selected sample fruit were removed and the juice of each fruit was extracted separately. The juice was strained using a muslin cloth to get the juice sample with no traces of pulp. All the beakers containing the sample juice were labeled properly and were subjected to chemical analysis. TSS, titratable acidity, ascorbic acid (vitamin C), reducing sugar, non-reducing sugar and total sugar were determined by the method described by the Association of Official Analytical Chemists (AOAC, 2016). TSS (°Brix) was measured using the handheld refractometer.

Tritatable acidity (% Acidity = titer value x normality of alkali x milliequivalent wt. of acid x 100/ volume of sample taken) was determined by titration method (AOAC, 2016). The juice sample added with 2-3 drops of phenolphthalein indicator was titrated against 0.1 N NaOH solution drop by drop with continuous stirring till the appearance of faint pink colour.

Ascorbic acid (expressed as mg/100g of fruit sample) was determined by titration method. A known volume of sample fruit juice prepared in 3% metaphosphoric acid was titrated against 2,6-dichlorophenol- indophenol dye solution as described in AOAC (2016). Ascorbic acid (mg/100g) was calculated using the formula, titer × dye factor × volume made up × 100/aliquot of extract taken × weight of fruit sample (g). For estimation of reducing sugar, AOAC (2016) was followed. 10 mL of kiwifruit juice was neutralized by 1N NaOH and 2 mL of 45% lead acetate was added, to which the distilled water was added to make the final volume of 250 ml. 10 mL of Fehling solution was prepared in another flask to which sample was added in presence of 2-3 methylene blue indicator. Titration was continued till the appearance of a brick-red colour. The titre value was recorded for calculation using the formula: Reducing sugar (%) = (Factor × dilution / Titre × volume of sample) x 100. Total sugar was estimated by titration method (AOAC, 2016). An aliquot of 50 mL of the clarified, de-leaded filtrate was used as titrant for titration against Fehling's solution. The titer was recorded for the calculation of total sugar

Total sugar = Factor x dilution/titer x volume of sample x 100.

Non-reducing sugar was estimated by subtracting reducing sugar from the total sugar. Non-reducing sugar was multiplied by 0.95 to express as sucrose percentage.

All the parameters were estimated in triplicate whereas the physical parameters were estimated with six replications. Multiple comparisons were done by Duncan's multiple range test (DMRT) to identify the difference among the treatment using the freely available version of the OPSTAT statistical software package (Sheoran *et al.,* 1998). The significance of the variation was considered at a 5 % ($P < 0.05$) level of significance. Mean values were superscripted by different letters signifying the differences between each other.

Results and discussion

Fruit weight and fruit diameter: The data recorded for fruit weight and fruit diameter of the samples representing different cultivars collected from different locations of India is presented in Table 1. It was depicted that the Bruno cultivar of kiwifruit (95.84 g) attended the highest fruit weight when compared to Abbot (42.38 g) irrespective of the location of collections. Similar trends were observed in fruit diameter varying in the range of 123.00 mm in cultivar Abbott to 168 mm in Hayward. Fruit weight and fruit diameter differed significantly among the different cultivars.

Fruit length and fruit volume: The fruit length and fruit volume were found highest in Bruno, *i.e.*112 mm and 92.83 cc and lowest in Abbott *i.e.*, 53.66 mm and 40.33 cc, respectively. The data on fruit length and fruit volume showed considerable variations among different cultivars of kiwifruit (Table 2).

Fruit density and fuzziness: All the samples collected from different locations showed non-significant differences among the cultivars for fruit density (Table 3). Similarly, fuzziness in all the cultivars with dense hair was recorded.

Table 3. Fruit density (g/cm^3) for different cultivars of kiwifruit grown in different locations in India

Location	Abbott	Allison	Bruno	Hayward	Monty
Sikkim	0 .82^a	1.04^a	1.02^a	1.00^a	1.02^a
Nagaland	0.94^a	1.02^a	1.01^a	1.01^a	0.96^a
Arunachal Pradesh	0.86^a	0.97^a	0.97^a	0.99^a	1.01^a
Himachal Pradesh	0.87^a	1.02^a	0.98^a	1.00^a	1.03^a

All values are mean, n=6. Values in the column superscripted by different letters are significantly ($P < 0.05$) different from each other (Duncan's new multiple range test).

TSS and titratable acidity: The data presented in Table 4 exhibit significant variation in TSS in all the cultivars namely Abbot, Allison, Bruno, Hayward and Monty whereas the titratable acidity of Allison and Bruno was significantly different, though

Table 1. Fruit weight (g) and fruit diameter (mm) for different cultivars of kiwifruit grown in different locations of India

Location	Fruit weight (g)					Fruit diameter (mm)				
	Abbott	Allison	Bruno	Hayward	Monty	Abbott	Allison	Bruno	Hayward	Monty
Sikkim	50.49^a	89.34^a	89.13^a	90.73^a	90.87^a	125.83^a	139.66^a	135.66^a	168.00^a	147.66^a
Nagaland	45.67^b	62.74^b	68.76^b	88.50^a	85.27^a	124.00^a	132.66^b	127.66^b	160.00^b	143.52^b
Arunachal Pradesh	42.59^b	63.54^b	95.84^a	89.58^a	65.93^b	123.82^a	139.60^a	144.50^c	163.33^b	143.50^b
Himachal Pradesh	42.38^b	55.86^c	68.59^b	76.89^b	62.82^b	123.00^a	124.00^c	125.00^b	157.50^c	138.16^c

Table 2. Fruit length (mm) and fruit volume (cc) for different cultivars of kiwifruit grown in different locations of India

Location	Fruit length (mm)					Fruit volume (cc)				
	Abbott	Allison	Bruno	Hayward	Monty	Abbott	Allison	Bruno	Hayward	Monty
Sikkim	66.33^a	94.00^a	91.00^b	86.33^a	93.00^a	51.16^a	85.50^a	87.16^a	90.33^a	88.83^a
Nagaland	65.50^a	72.50^c	82.50^c	76.00^c	82.50^b	48.50^b	61.33^b	70.16^b	87.66^a	88.50^a
Arunachal Pradesh	61.33^b	84.00^b	112.00^a	82.33^b	82.33^b	41.00^c	63.83^b	92.83^a	88.16^a	65.16^b
Himachal Pradesh	53.66^c	70.50^c	79.66^c	73.66^c	80.33^b	40.33^c	53.33^c	70.00^b	76.16^b	60.66^b

All values are mean, n=6. Values in the column superscripted by different letters are significantly ($P < 0.05$) different from each other (Duncan's new multiple range test).

no significant difference was recorded in the cultivars Abbot, Hayward and Monty. TSS varied from 11.16 °Brix in Monty to 17.03 °Brix in Allison whereas titratable acidity showed 0.43 % in Allison and Bruno to 0.76% in Monty.

Ascorbic acid and reducing sugar: Chemical characteristics of fruits in terms of ascorbic acid and reducing sugar showed significant variations in all the cultivars (Table 5). Cultivar Bruno was found to be significantly superior in all the locations followed by Monty in terms of ascorbic acid whereas the reducing sugar was as low as 4.79 % in cultivar Monty and as high as 7.10 % in cultivar Abbott.

Non-reducing sugar and total sugar: Data of non-reducing and total sugar in different cultivars collected from different locations is presented in Table 6. Non-reducing sugar varied from 5.68 % in Abbot to 6.30 % in Allison. Interestingly, a similar trend of total sugar was recorded in the range of 11.26 % in Abbott to 12.99 % in Allison.

The above data for physico-chemical parameters showed statistically significant variation in all the cultivars of kiwifruit grown in different locations. Singh *et al.* (2012) studied different attributes of kiwifruit and revealed that Abbott's weight was 52.86 gm which was in range with the present study. Nishiyama *et al.* (2004) also reported that the fruit weight in cultivars Bruno and Hayward are 101.3 and 99.6gm, respectively and examined the density of hairs *i.e.* fuzziness in cultivars Abbott, Bruno and Hayward which has a similar finding with the current study. Fruit diameter in Hayward varied in range (157.50- 168.00 mm), fruit length in Abbott (53.66 - 66.33 mm), Allison (70.50 - 94.00 mm) and fruit volume in Allison (53.33- 85.50 cc) were having a similar range reported by Kishor *et al.* (2017). A similar result was also stated by Yildrim *et al.* (2011) and Popovic *et al.* (2002) regarding the fruit length in Abbott. Fruit density in the present study was in a range of 0.82-1.04 g/cm^3 which is consistent with Shahkoomahally *et al.* (2015) and Leahu *et al.* (2013).

The chemical parameters for the studied cultivars showed variation across different traits. The total soluble solids (TSS) ranged from 12.53 to 14.53 °Brix in Abbott, 13.80 to 17.03 °Brix in Allison, 12.30 to 14.56 °Brix in Bruno, 11.73 to 16.70 °Brix in Hayward, and 12.09 to 14.35 °Brix in Monty. Titratable acidity varied between 0.56 to 0.73% in Abbott, 0.43 to 0.66% in Allison, 0.43 to 0.70% in Bruno, 0.46 to 0.63% in Hayward, and 0.63 to 0.76% in Monty. Ascorbic acid content ranged from 80.00 to 80.61 mg per 100 g in Abbott, 89.33 to 92.27 mg per 100 g in Allison, 105.33 to 112.26 mg per 100 g in Bruno, 85.33 to 89.17 mg per 100 g in Hayward, and 98.00 to 102.53 mg per 100 g in Monty. The reducing sugar content ranged from 5.2 to 7.10% in Abbott, 5.86 to 7.04% in Allison, 5.10 to 6.93% in Bruno, 5.73 to 7.02% in Hayward, and 4.79 to 6.55% in Monty. Non-reducing sugar content varied between 5.68 to 6.31% in Abbott, 6.24 to 6.44% in Allison, 5.94 to 6.90% in Bruno, 5.79 to 6.19% in Hayward, and 5.92 to 6.75% in Monty. The total sugar content ranged from 11.26 to 12.81% in Abbott, 11.88 to 12.99% in Allison, 11.75 to 12.53% in Bruno, 11.46 to 12.86% in Hayward, and 11.30 to 12.45% in Monty. These results highlight the variability in chemical composition among the cultivars grown at different places.

These results are in agreement with the findings of Fourie and Hansmann (1992), Popovic *et al.* (2002), Nishiyama *et al.* (2004), Fattahi *et al.* (2010), Mahboube *et al.* (2010), Zolfaghari *et al.* (2010), Marsh *et al.* (2011), Yildrim *et al.* (2011), Park *et al.* (2014), Pal *et al.* (2015), Sharma *et al.* (2015), Shahkoomahally *et al.* (2015), Cotrut *et al.* (2016), Rakha *et al.* (2017), and Yuan *et al.* (2023). TSS in the present work showed that cultivar Allison recorded superiority over the rest of the cultivars in all the locations studied. These results are consistent with the findings of Kishor *et al.* (2017) and Singh *et al.* (2012) who reported the highest TSS in cultivar Allison amongst the cultivars they investigated. The reduction in titratable acidity was the result

Table 4. TSS (°Brix) and titratable acidity (%) for different cultivars of kiwifruit grown in different locations in India

Location	TSS (°Brix)					Titratable acidity (%)				
	Abbott	Allison	Bruno	Hayward	Monty	Abbott	Allison	Bruno	Hayward	Monty
Sikkim	13.43^c	15.90^a	12.70^b	11.80^c	12.09^c	0.66^a	0.56^a	0.63^a	0.56^a	0.73^a
Nagaland	13.86^b	16.36^a	13.33^b	15.36^b	13.56^b	0.60^a	0.46^b	0.46^b	0.50^a	0.66^a
Arunachal Pradesh	14.53^a	17.03^a	14.56^a	16.70^a	14.35^a	0.56^a	0.43^b	0.43^b	0.46^a	0.63^a
Himachal Pradesh	12.53^d	13.80^b	12.30^b	11.73^c	11.16^d	0.73^a	0.66^a	0.70^a	0.63^a	0.76^a

Table 5. Ascorbic acid (mg/100g) and reducing sugar (%) for different cultivars of kiwifruit grown in different locations of India

Location	Ascorbic acid (mg/100g)					Reducing sugar (%)				
	Abbott	Allison	Bruno	Hayward	Monty	Abbott	Allison	Bruno	Hayward	Monty
Sikkim	80.20^a	90.33^b	107.33^c	86.66^b	100.33^a	6.19^c	6.33^b	6.07^c	6.23^b	5.63^c
Nagaland	80.46^a	91.72^a	109.66^b	88.00^a	101.53^a	6.73^b	6.93^a	6.51^b	6.86^a	6.07^b
Arunachal Pradesh	80.61^a	92.27^a	112.26^a	89.17^a	102.53^a	7.10^a	7.04^a	6.93^a	7.02^a	6.55^a
Himachal Pradesh	80.00^a	89.33^c	105.33^d	85.33^c	98.00^b	5.21^d	5.86^c	5.10^d	5.73^c	4.79^d

Table 6. Non-reducing sugar and total sugar (%) for different cultivars of kiwifruit grown in different locations in India

Location	Non-reducing sugar (%)					Total sugar (%)				
	Abbott	Allison	Bruno	Hayward	Monty	Abbott	Allison	Bruno	Hayward	Monty
Sikkim	5.68^a	6.44^a	6.19^b	5.94^a	5.92^b	11.56^c	12.46^b	11.96^b	11.86^c	11.28^c
Nagaland	5.78^a	6.24^a	6.07^b	5.79^a	6.35^a	12.18^b	12.83^a	12.27^a	12.31^b	12.12^b
Arunachal Pradesh	6.07^a	6.30^a	5.94^b	6.19^a	5.89^b	12.81^a	12.99^a	12.53^a	12.86^a	12.45^a
Himachal Pradesh	6.31^a	6.30^a	6.90^a	6.01^a	6.75^a	11.26^d	11.88^c	11.75^b	11.46^d	11.30^c

All values are mean, n=3. Values in the column superscripted by different letters are significantly ($P < 0.05$) different from each other (Duncan's new multiple range test).

of the metabolism of organic acids during the ripening process (Matsumoto *et al.*, 1983) and the conversion of organic acids into sugars (Deshmukh *et al.*, 2016). The variation in TSS in different kiwifruit may be due to genetic differences amongst cultivars (Chandel *et al.*, 2004). According to Latocha (2007) the amount of vitamin C could be affected by growing conditions such as soil, fertilization, irrigation, temperature, genotype and due to factors like maturity and harvesting methods, post-harvest handling procedures (Lee and Kader, 2000). The amount of variation observed in different kiwifruit cultivars, in terms of physico-chemical attributes, grown in different locations may be due to environmental factors, nutrition, cultivation practices, genotype, location it grows (geographical aspects), climatic condition, cultivation practices, time of maturity and harvesting. These findings are similar to the results reported by Doharey *et al.* (2007), Kumar and Yadav (2008), Rana *et al.* (2011), Shukla and Shukla (2017), and Zhang *et al.* (2020), who also observed that fruit quality is influenced by environmental factors and genetic characteristics. Reddy *et al.* (2015) reported that the fuzzy kiwifruit occurs in the species *Actinidia deliciosa*. The variations on the physico-chemical may be attributed to the prevailing climatic conditions of the site like temperature, rainfall, humidity (Khalid *et al.*, 2018) and factors such as air, soil and day length *i.e.*, photoperiod (Bunker and Salinger, 1987), cultivation techniques, nutrition, irrigation and pruning (Boukouvalas and Chouliaras, 2005) which plays an important role in fruit quality.

Despite the variations in different parameters for the cultivars and locations, the quality of the fruit in the all samples collected from North Eastern states of Sikkim was at par with the traditional growing area (Himachal Pradesh). This set down the fact that the commercial cultivation of kiwifruit can be intensified in the region with the support of the market and value chain. The findings of the present study will help in the expansion of the area under kiwi cultivation especially in the states of Sikkim, Arunachal Pradesh and Nagaland.

The study revealed that the physicochemical properties of kiwifruits are significantly different depending on genotype, geography, climate, cultivation practices, and harvesting time. Traditionally a kiwifruit hub in India, Himachal Pradesh is now competing with Northeastern states like Arunachal Pradesh, Nagaland and Sikkim where superior quality fruits have been observed. For example, TSS, ascorbic acid and sugar content of five cultivars (Abbott, Allison, Bruno, Hayward and Monty) in Arunachal Pradesh samples were higher than in other locations. The suitability of Northeastern India's climate for quality kiwifruit production is underscored by these findings. In order to take advantage of these variations, innovative marketing strategies and improved post harvest practices, including grading and packaging, are suggested. Further location specific studies with larger samples and microclimate analysis can improve production, improve fruit quality and increase regional farmer incomes.

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